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U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭ'lo
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
A	ampere(s)	
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps=2.22×10^{12} dpm
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	3.527×10^{-2} ounces= 2.205×10^{-3} pounds
Hz	hertz	cycle per second
kVp	kilovolt peak	
m	meter(s)	39.4 inches=3.28 feet
m^3	cubic meter(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
mi	mile(s)	
ml	milliliter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g
r/min	revolutions per minute	
s	second	
yr	year	

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RADIATION DATA AND REPORTS

Volume 15, Number 7, July 1974

Radiation Data and Reports, a monthly publication of the Environmental Protection Agency presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

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U.S. ENVIRONMENTAL PROTECTION AGENCY

Russell E. Train, Administrator

Reports

Environmental Radiation Effects of Nuclear Facilities in New York State

Michael S. Terpilak and Bruce L. Jorgensen [1]

The annual quantities and types of radioactive materials released from three operating nuclear electric generating facilities, a national laboratory, and a nuclear fuels reprocessing facility are presented and discussed. The period of interest spans the years 1969 through 1972 with some additional data for those facilities operating before 1969. Release quantities have been well controlled, considering the nature and vintage of the operations.

Results of environmental surveillance relying most heavily on the activities of the New York State Department of Environmental Conservation, are presented. Observations at Indian Point Station Unit No. 1 and at Nuclear Fuel Services have led to the discovery of several facility-related radioisotopes in environmental media. These two facilities are of comparatively early vintage, have produced slightly larger amounts of waste materials and have been the subject of more comprehensive studies than others in the State.

Dose consequences to hypothetical individuals and to populations within 50 miles of the facilities are addressed. It should be stressed that all individual doses presented are hypothetical. Doses via the drinking water and cow's milk pathways are particularly conservative. In each case, these hypothetical doses are at least an order of magnitude or more greater than the known worst case. No excessive exposure levels are known to have existed. All operations have resulted in postulated exposure levels well within applicable regulations or guidelines, generally being a small percentage of these values. Population doses have been surprisingly consistent through the period of interest. They are insignificant in comparison to the dose to the population of the State from natural or medical sources.

In most regions of the United States, the principal sources of environmental radiation are natural background and fallout from weapons tests. In the State of New York, however, three operational nuclear power facilities (*1–5*), one nuclear fuels reprocessing plant (*6*), two large research facilities, one Atomic Energy Commission national laboratory and numerous additional research, manufacturing, medical, and disposal facilities also contribute to environmental radiation.

Natural background and fallout data are monitored by the State Department of Environmental Conservation and the Environmental Protection Agency through the National Environmental Surveillance Networks. Environmental surveillance data concerning nuclear facilities are provided by the State Department of Environmental Conservation (*7–9*), the U.S. Atomic Energy Commission (AEC), nuclear facility operators, and special studies by interested parties.

This report deals with data from the environmental radiation surveillance programs in New York. It assesses the contributions that fixed facilities handling radioactive materials make to environmental radiation.

Solid wastes

Solid radioactive waste is generally removed from a nuclear facility site by a private contractor and is buried at an approved location in a manner such that there is expected to be no uncontrolled contribution of radioactivity to the environment from this source. New York has such a licensed burial facility in Cattaraugus County near the site of the fuels reprocessing plant. A compilation of the inventory of buried

[1] Environmental Protection Agency, Environmental Radiation Program, Region II, 26 Federal Plaza, New York, New York 10007.

materials is given in table 1. A second AEC-licensed facility for the burial of high level wastes is also located at Nuclear Fuel Services (NFS). A compilation of the inventory of buried materials at this site is given in table 2 (*10*). A total of almost one million curies has been buried at these sites.

The State Department of Environmental Conservation (DEC) monitors (*7–9*) surface water samples from the vicinity of the burial sites to determine that significant migration out of the trenches or holes is not taking place (*4–6*). Analyses for the following nuclides have been made, with the noted results:

Cesium-137	None detected	1969–1972
Cobalt-60	None detected	1969–1972
Ruthenium-106	None detected	1969–1972
Zirconium-niobium-95	None detected	1971–1972
Cesium-134	Maximum of 20 pCi/liter in	1970
Manganese-54	None detected	1970–1972
Zinc-65	None detected	1970–1972
Strontium-89	Maximum of 7 pCi/liter in	1969
Strontium-90	Maximum of 15 pCi/liter in	1971
Gross beta[2]	Maximum of 228 pCi/liter in	1971 (4-year average, 25 pCi/liter)
Gross alpha	None detected	1971–1972
Tritium	Maximum of 21 650 pCi/liter in	1972 (4-year average, 4 990 pCi/liter)
Uranium	None detected	1969–1972

The DEC concludes that no significant surface discharges or underground seepages from the burial site have occurred. The origin of the minor discharges that have occurred is presently being investigated by the DEC in a cooperative effort with the New York State Atomic and Space Development Authority and the U.S. Environmental Protection Agency.

Major facilities and their surveillance programs

The distribution of major nuclear facilities in the State of New York is shown in figure 1.

A summary of the characteristics and locations of operating and scheduled nuclear-electric generating facilities in New York is given in table 3. A listing of other major nuclear facilities is given in table 4. Three nuclear power reactors were in operation during 1972; Indian Point Station Unit 1, Nine Mile Point Nuclear Station Unit 1, and R. E. Ginna Nuclear Power Plant Unit 1. Environmental surveillance programs for these nuclear-electric facilities in the State are summarized in table 5. Preoperational environmental surveillance programs and data for other electric generating facilities are also discussed.

Indian Point Station Unit 1

Indian Point Station Unit 1, located 25 miles north of New York City, owned and operated by Consolidated Edison Company, is on the Hudson River in the village of Buchanan, Westchester County. It was the first private nuclear power reactor in New York State, starting operations on September 16, 1962. This unit is a pressurized water reactor with a rated power of 285 megawatts electric. Condenser cooling water is withdrawn from and discharged to the Hudson River. Two villages, Verplanck and Buchanan, each with a population of less than 2100, are approximately 0.8 miles from the reactor. Peekskill, population 19 000, is approximately 2 miles northeast of the site. The estimated population within a 10-mile radius of the site is 160 000.

[2] Exclusive of tritium.

Table 1. NFS low-level waste burial inventory

Trench number	Burial dates		Waste volume (cubic feet)	Percentage of volume by source						Byproduct material [g] (curies)	Plutonium-238 (curies)	Source material [g] (pounds)	Special nuclear material (grams)
	Start	Stop		(a)	(b)	(c)	(d)	(e)	(f)				
1	11/63	5/64	55 275	0.7	1.1	41.8	4.8	0	51.6	4 117	0	739	2 858
2	5/64	10/64	114 246	3.0	.2	24.0	53.6	0	19.2	2 215	0	553	659
3	7/64	11/65	198 675	5.2	.4	19.9	40.0	0	34.5	17 061	0.1	44 583	1 894
4	10/65	6/67	274 416	4.0	1.0	21.9	23.7	11.8	37.6	67 117	0	140 825	8 333
5	5/67	2/69	278 401	2.0	1.3	16.2	22.1	21.2	37.2	90 432	2 400	24 924	3 579
6	7/70	10/70	75	0	0	0	0	0	100.0	10 245	0	0	0
7	11/65	3/66	2 465	0	0	5.7	0	0	94.3	1 568	0	0	0
8	1/69	11/70	252 435	.6	2.0	16.0	24.6	25.2	31.6	34 757	3 914	321 226	13 074
9	10/70	6/71	173 722	1.6	1.5	9.0	14.0	18.7	55.2	27 323	6 835	43 777	4 550
10	6/71	5/72	182 462	5.8	2.9	8.5	15.5	84.4	33.0	39 887	15 006	101 614	3 139
11	5/72	12/72	182 769	6.8	1.5	10.2	31.3	15.1	35.0	46 704	6 827	80 092	6 151
Total			1 714 941							341 426	34 982	758 333	44 237
Average				2.7	1.1	15.7	20.9	11.5	48.1				

[a] Nuclear power plants.
[b] Institutional, educational and hospitals.
[c] Federal government.
[d] Industrial, pharmaceutical manufacturing, and research.
[e] NFS operations.
[f] Waste disposal and decontamination companies.
[g] Byproduct material percentage constituents: ^{3}H and ^{14}C, 46.4 percent = 168 420 Ci mixed fission products and miscellaneous, 31.0 percent = 105 840 Ci, ^{60}Co, 22.5 percent = 76 820 Ci, ^{137}Cs, ^{129}I, ^{131}I, ^{226}Ra, and ^{241}Am, 0.1 percent.
[h] Of total 758 333 pounds; 744 045 are uranium-238 and natural uranium with remainder thorium-232.

Liquid waste discharges

During normal plant operations, liquid waste from Indian Point Station Unit 1 is monitored for radionuclide content and is discharged at a controlled rate into the Hudson River through the cooling water discharge canal to assure compliance with technical specifications associated with the AEC operating license (*11*).

The quantities of radioactive liquid waste discharged from Indian Point Station Unit 1 are shown in table 6. The plant was shut down for refueling and repairs during much of 1970. The annual average doses given in this table are those that would be received internally by a hypothetical person consuming 100 g/day of fish from Green's Cove. There are no municipal drinking water intakes downstream of the Indian Point site.

Gaseous waste discharge

The radioactive gaseous wastes discharged from Indian Point Station Unit 1 are shown in table 7 (*3,11*). The average annual doses shown in this table are site boundary doses that would be received externally by the skin from radioactive noble gases and internally by the infant thyroid from iodine via milk consumption. Observed concentrations of particulates are lower than the MPC_{air} by a factor of approximately 100.

Environmental monitoring

Table 8 lists gross beta analyses of environmental samples (*7–9*) collected in the vicinity of Indian Point. The activity of onsite air particulate samples collected by Consolidated Edison varied from less than 0.1 pCi/m³ to 0.89 pCi/m³ in 1970 with the lower values in the winter and the higher values in the summer (*12*). Such variations are generally attributable to the seasonal transfer of radioactive fallout from the stratosphere.

The gross beta radioactivity in offsite particulate air samples, as indicated in table 8, varied from nondetectable to a maximum of 1.08 pCi/m³. No radioiodines have been identified in either onsite or offsite air samples. For the purpose of comparison, the gross beta activity in air particulate samples collected in Albany, Buffalo, and New York City by the

Table 2. NFS high-level burial site inventory summary [a]

Year	Number of holes	Total volume (cubic feet)	Total activity (curies)	MFP [b] (curies)	Zirconium-95 (curies)	Cobalt-60 (curies)	Mix [c] (curies)
1972	44	51 965	50 186	49 502	—	684	—
1971	27	8 125	373 663	98 705	223 075	51 883	0.05
1970	21	6 767	71 371	31	—	71 340	—
1969	20	7 821	25 862	10	—	25 852	.018
1968	17	7 146	2 669	25	46	2 598	—
1967	17	4 718	21 723	525	33	21 052	113
1966	5	1 236	534	24	2	0.109	508
Total	151	87 778	546 008	148 822	223 156	173 409	621

[a] Total curies buried at NFS: 376 408 at low-level site, 546 008 in high-level holes, 922 416 total.
[b] MFP—mixed fission products.
[c] Mix—mixed radionuclides (unidentified).

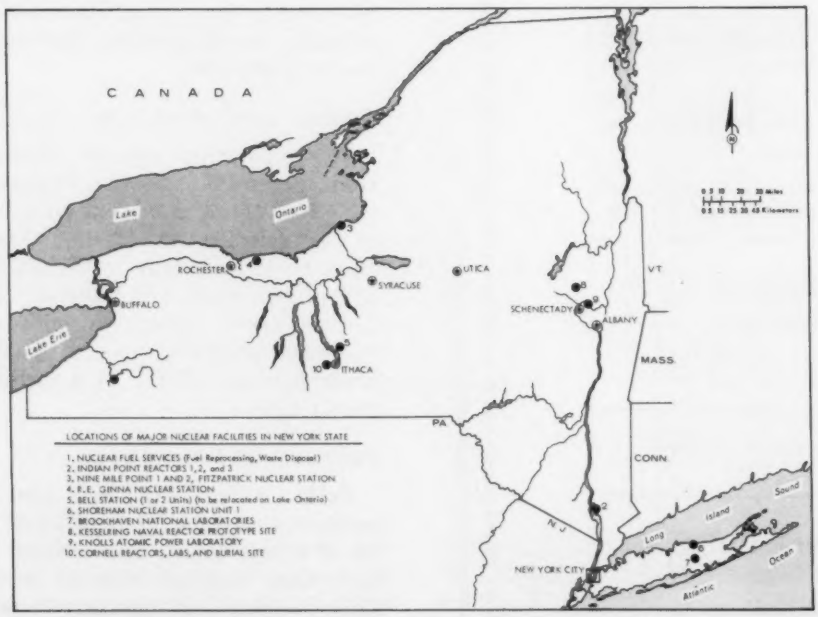

Figure 1. Major nuclear facilities in New York State

Radiation Alert Network varied typically from nondetectable to 1 pCi/m^3.

The gross beta radioactivity in water samples taken offsite varied from nondetectable to a maximum of 183 pCi/liter. Data from Albany County, which was used as a background sample, varied from nondetectable to 11 pCi/liter in the years 1970 through 1972 (*7–9*). According to the Department of Environmental Conservation, "Samples of water from the lower Hudson River show higher gross beta results because of the effect of naturally occurring potassium-40 and the intrusion of saltwater up the river" (*7*).

Figure 2 shows the locations of the environmental sampling stations in relation to the plant (*13*).

The data in tables 6 and 7 have limited quantitative value for the purpose of evaluating the exposure to the general population resulting

Table 3. Characteristics of nuclear electric generating facilities in New York State

Facility	Owner	Reactor type [a]	Power level		Year of startup	Location	Approximate population within 10 miles [b]
			MW(e)	MW(t) net			
Indian Point Station Unit 1	Consolidated Edison Company	PWR	265	615	1962	Indian Point	160 000
Indian Point Station Unit 2	Consolidated Edison Company	PWR	873	2 758	1973	Indian Point	160 000
Indian Point Station Unit 3	Consolidated Edison Company	PWR	965	3 025	1975	Indian Point	
Nine Mile Point Nuclear Station Unit 1.	Niagara Mohawk Power Corporation.	BWR	610	1 850	1969	Scriba	31 000
Nine Mile Point Nuclear Station Unit 2.	Niagara Mohawk Power Corporation.	BWR	1 150	3 223	1978	Scriba	
James A. Fitzpatrick Nuclear Power Station	Power Authority [c] of State of N.Y.	BWR	848	2 436	1974	Scriba	31 000
R. E. Ginna Nuclear Power Plant Unit 1.	Rochester Gas and Electric Company	PWR	420	1 300	1969	Rochester (Ontario, N.Y.)	27 000
Shoreham Nuclear Power Station	Long Island Lighting Company	BWR	849	2 436	1977	Brookhaven	
Bell Station	NYS Electric and Gas Company	BWR	866	2 436	1980's	Lake Ontario	
Total	6 Companies	9 Power Plants	6 846	20 079		5 locations	

[a] BWR, boiling water reactor.
PWR, pressurized water reactor.
[b] Operating facilities only.
[c] To be operated by Niagara Mohawk Power Corporation under contract.

Table 4. Major nuclear facilities in New York State other than nuclear power generating facilities

Facility	Location	Startup date	Type of operation
Nuclear Fuel Services, Inc:	West Valley, Cattaraugus County, N.Y.	1966	Nuclear fuel reprocessing plant storage of high level waste fission products
	Burial site West Valley Cattaraugus County, N.Y.	1963	Solid radioactive wastes shipped mainly from facilities in Northeast States buried in trenches
Brookhaven National Laboratory:	Upton, Suffolk County, N.Y.	1951	Testing and research reactors, (HFBR), (MRR)
Knolls Atomic Power Laboratory:	West Milton, Saratoga County, N.Y.	1955	Testing and research reactors
Knolls Atomic Power Laboratory, Knolls site, General Electric Company:	Schenectady, Schenectady County, N.Y.	1949	Testing and research reactor
Cornell Nuclear Reactor Laboratory, Cornell University:	Ithaca, Tompkins County, N.Y.	1962	Research and training reactors-(TRIGA MARK II), (ZPR)
Western New York Nuclear Research Center, University of Buffalo:	Buffalo, Erie County, N.Y.	1961	Research reactor-(PULSTAR)
United Nuclear Corporation Remote Experimental Station:	Pawling, Dutchess County, N.Y.	1961	Heavy water nuclear reactor 5 watts thermal (PRR) (abandoned 3/74)
Union Carbide Corporation, Sterling Forest Research Center:	Sterling Forest, Orange County, N.Y.	1961	5MW pool type, light water research reactor (UCNR), produces pharmaceutical radioisotopes
Cornell burial site:	Lansing, Tompkins County, N.Y.	1960	Burial of waste from numerous research projects on campus
National Lead Company, Nuclear Metals Division:	Albany, Albany County, N.Y.	1960	Fabrication of depleted uranium counter weights, some fabrication of uranium fuel elements

from liquid and gaseous releases from a nuclear facility (*14*). However, they might be useful for indicating when new injections of radioactivity into the environment, thus serving as a basis for further investigation by more detailed radionuclide analysis.

Such radionuclide analyses are made by the State Department of Health for the Department of Environmental Conservation (*7–9*). A summary of results of some of these analyses for aquatic vegetation, and silt is contained in tables 9, 10, and 11. Some results of the opera-

Table 5. Environmental radiation surveillance programs in New York State

Media	Indian Point Station			R. E. Ginna Nuclear Power Station			Nine Mile Point Nuclear Station		
	Number of locations	Frequency of collection	Type of analysis	Number of locations	Frequency of collection	Type of analysis	Number of locations	Frequency of collection	Type of analysis
Airborne halogens:							11	Weekly	Gamma spectrum analysis
Air particulates + organic iodides:	5 with 3 other locations for 1 wk consecutively	Weekly	Gross beta, gamma scan				11	Weekly Monthly	Gross beta, gamma scan
External radiation: (direct)	Along principal roads within 5-mile radius	Annually	Gamma background						
	Selected locations	Monthly	Gamma background						
Gamma radiation monitors:							6	Continuous	Gross gamma
Fallout:	2	Monthly	Gross beta, tritium						
Precipitation:							11	Monthly	Gross beta, gamma scan
Milk:					Monthly grab	Gross beta	Adjacent dairy	Monthly	^{131}I, gross beta, ^{90}Sr
Surface water					Monthly	Gross beta			
River water	2	Weekly	Gross beta, tritium on monthly composite						
Lake water	3	Monthly grab	Gross beta, tritium	2	Weekly	Gross beta	Downstream of effluent discharge	Weekly	Gross beta, gamma scan
Creek water:					Monthly grab	Gross beta			
Reservoir water: (Deer Creek)	3	Monthly grab	Gross beta, tritium						
Well water:	3	Monthly grab	Gross beta, tritium		Monthly grab	Gross beta			
Bottom sediment:	5	Spring, summer, fall	Gross beta, gamma scan		Annually	Gross beta			
Soil:	5	Annually	Gross beta, gamma scan						
River aquatic vegetation:	5	Spring, summer, fall	Gross beta, gamma scan						
Lake aquatic vegetation:	3	Spring, summer, fall	Gross beta, tritium						
Vegetation:	5	Spring, summer, fall	Gross beta, gamma scan						
Clams:							2	Spring, fall	Gross beta, gamma scan, ^{90}Sr
Fish:	Where available	Monthly	Gross beta, gamma scan		Quarterly	Gross beta	2	Spring, fall	Gross beta, ^{90}Sr
Gammarus: (freshwater shrimp)							2	Spring, fall	Gross beta, gamma scan, ^{90}Sr
Film badges or TLD'S:							11	Monthly	Gross gamma
Human bone:							2	Spring, fall	Gross beta, gamma scan, ^{90}Sr

See footnotes at end of table.

Table 5. Environmental radiation surveillance programs in New York State—continued

Media	New York State			Nuclear Fuel Services			Atomic Energy Commission		
	Number of locations	Frequency of collection	Type of analysis	Number of locations	Frequency of collection	Type of analysis	Number of locations	Frequency of collection	Type of analysis
Air:	16	Varies	Gross beta, ^{85}Kr around NFS	4	1 daily 3 weekly	^{85}Kr, gross alpha, gross beta	1 2 3	Daily Weekly Monthly	Gross alpha, gross beta Gross alpha (monthly HTO)
External radiation: (direct)							6	Monthly	Gross gamma
Milk:	31	Varies	Gross beta, ^{131}I, ^{137}Cs, ^{140}Ba, ^{40}K, ^{90}Sr, ^{89}Sr, ^{3}H, other gammas	4 2	Weekly Annual	^{129}I, ^{90}Sr, ^{131}I, ^{134}Cs, ^{137}Cs	2	Quarterly	Gamma-spectrum + iodine-131-separation
Algae or vegetation:	9	2/a	Gamma scan				11	Yearly	Gamma spectrum
Fish:	12	2/a	Gamma scan (^{89}Sr, ^{90}Sr around Con Ed)	1	2/a	Bone—^{90}Sr, Flesh—^{134}Cs, ^{137}Cs, ^{90}Sr	3	Yearly	Gamma spectrum
Deer:	4–5	2/a	^{90}Sr, ^{129}I,[a] Pu gamma in lung	1	Annual	Bone—^{89}Sr, ^{90}Sr, Flesh—^{134}Cs, ^{137}Cs, ^{90}Sr			
Soil:							10	Semi-annual	Gamma spectrum
Bottom sediment:	5	2/a	Gamma scan				11	Yearly	Gamma spectrum
Silt:				1	Quarterly	Gross beta, gross alpha, gamma scan			
Precipitation:		After each rain	^{89}Sr, ^{90}Sr		Monthly	Tritium		After each rain Monthly composite	Gross alpha, gross beta HTO, ^{90}Sr, gamma spectrum
Surface water:	37	Varies—monthly or weekly	Gross beta (^{3}H, ^{89}Sr, ^{90}Sr on selected samples)	6	Varies—quarterly, monthly, or weekly	Varies—gross alpha, gross beta, ^{3}H, ^{106}Ru, (^{129}I), ^{134}Cs, ^{137}Cs, ^{89}Sr, ^{90}Sr, U isotopic, Pu isotopic	10	Monthly grab	Gross alpha, gross beta, HTO
Public water supply:	21	Varies	Gross beta (^{3}H, ^{89}Sr, ^{90}Sr on selected samples)						
Ground water:	8	Annually	Gross beta, tritium				16	Monthly	Gross alpha, gross beta, HTO [^{90}Sr, gamma spectrum (quarterly)]
							34	Quarterly	Gross alpha, gross beta, HTO [^{90}Sr, gamma spectrum (semi-annually)]
							26	Semiannual	Gross alpha, gross beta, HTO [^{90}Sr, gamma spectrum (annual)]
Fallout [b]:	2	Weekly	^{89}Sr, ^{90}Sr, ^{3}H, gamma scan		Monthly	Gross alpha Gross beta			

[a] Program around Nuclear Fuel Services only.
[b] Denotes radioactive material originating from atmosphere and settling or being washed into a bucket.
[c] Calculated based on dilution.

Table 6. Quantities of radioactive liquid waste discharged by the Indian Point Station 1 [a]

Year	Mixed fission and corrosion products				Tritium		
	Curies released	MPC [b] (pCi/liter)	Annual average percent MPC	Annual dose [c] (mrem)	Curies released	Annual average percent MPC	Annual dose [c] (mrem)
1962–1968	146 (21/yr avg)	7000	0.22 to 70.1	0.50 (average)	1210	0.058 (1968 percent MPC)	0.02 (1968 dose)
1969	28	7000	1.01	.60	1100	.08	.02
1970	7.8	7000	.28	.20	410	.03	<.01
1971	81	7000	2.91	.95	725	.053	.01
1972	25.4	7000	.91	.64	574	.04	.02
Projected future	40.0	7000	1.44	<1.0	1500	.11	.55

[a] All curie released data from final EIS Unit 2, Section III except 1972 data, 1972 data from reference *3*.
[b] The technical specifications require a more restrictive 1000 pCi/liter.
[c] For consumption of 100 g/day of fish from Green's Cove.

Table 7. Radioactive gaseous waste discharged by the Indian Point Station Unit 1

Year	Noble and activation gases				Halogens and particulates			
	Released (curies)	Permissible (curies)	Percent of permissible	Annual average dose [a] (mrem)	Released (curies)	Permissible (curies))	Percent of permissible	Annual average dose [a] (mrem)
1963–1968 [b]	166	3.2×10^{7}	0.001	0.005	(c)	45.6	—	—
1969	600	5.3×10^{6}	.01	.05	0.025	7.6	0.33	1.7
1970 [d]	1800	5.3×10^{6}	.03	.15	.075	7.6	1.0	5
1971 [d]	380	5.3×10^{6}	.007	.02	.21	7.6	2.8	14
1972 [e]	543	5.3×10^{6}	.009	.04	.928	7.6	12.4	62
Projected future maximum	1200	5.3×10^{6}	.02	.10	.37	7.6	4.9	25

[a] At plant perimeter.
[b] 1963–68 data from reference *4*.
[c] Negligible.
[d] 1969–71 curies released data from final EIS Unit 2, Section III, (*11*).
[e] 1972 data from reference *3*.

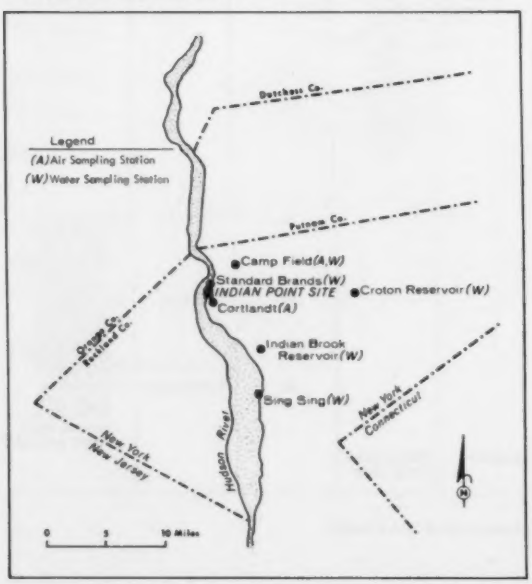

Figure 2. Environmental sampling locations Indian Point Station

tion of Indian Point Station Unit 1 can be seen in these tables.

The higher levels of cesium-134 and cesium-137 observed in fish and aquatic vegetation collected from Green's Cove can be attributed to liquid releases from Indian Point Station Unit 1 (*15*). High levels of cobalt-60 and manganese-54 observed in aquatic vegetation from Green's Cove and Tappan Zee Bridge in comparison to the other two sampling stations are attributed to releases from the Indian Point Station. The nuclides, cesium-137, ruthenium-106, and zirconium-niobium-95, are characteristic of fallout from weapons testing.

A concentration of 100 pCi/kg in fish flesh, (assuming 50 pCi/kg each of cesium-134 and cesium-137) would result in an annual whole body dose of 0.18 mrem if consumed at a rate of 100 g/day (*16*).

An "Environmental and Postoperational Survey for Radioactivity-Consolidated Edison Indian Point Reactors" (*13*) conducted by the

Table 8. Offsite gross beta radioactivity levels in air and water, Indian Point Station, 1968-1972

Station location		1968[a]	1969[a]	1970[a]	1971[b]	1972[c]
Air particulate concentrations: (pCi/m³)						
Peekskill:						
Camp Field Filter Plant:	Average	0.15	0.20	0.22	0.33	0.11
	Maximum	.49	.56	.46	1.08	.33
	Minimum	.10	.02	.04	.06	.02
Cortlandt:						
Department of Public Works:	Average	.10	.11	.27	.23	.09
	Maximum	.26	.33	.70	.73	.39
	Minimum	.01	ND	.05	.03	.02
Water concentrations: (pCi/liter)						
Peekskill:						
Hudson River at Standard Brands:	Average	17	9	14	12	8
	Maximum	52	32	37	183	57
	Minimum	4	ND	ND	ND	ND
Camp Field Reservoir:	Average	3	3	7	7	3
	Maximum	10	15	31	38	5
	Minimum	ND	ND	ND	ND	2
Yorktown:						
Croton Reservoir:	Average	4	4	10	5	4
	Maximum	5	6	80	28	8
	Minimum	1	ND	3	ND	2
Ossining:						
Hudson River at Sing Sing:	Average	25	23	29	20	15
	Maximum	117	71	68	65	68
	Minimum	4	ND	ND	ND	ND
Indian Brook Reservoir:	Average	5	4	6	3	4
	Maximum	7	7	13	7	5
	Minimum	4	ND	3	ND	3

[a] 1968–1970 data—reference *8*.
[b] 1971 data—reference *2*.
[c] 1972 data—reference *3*.
ND, nondetectable, below minimum detectable activity.

New York State Department of Environmental Conservation reports the results of a pressurized ionization chamber background survey for gamma radiation in the vicinity of Indian Point Station. The results of this survey are given in table 12. This table includes the average reading for all stations for 1964 through 1970. In general, it can be concluded that no significant or measurable increase in background gamma radiation occurred during those years of reactor operation. Figure 3 gives the locations of the ionization chamber stations used for this survey.

Pressurized ionization chamber readings of penetrating radiation in the vicinity of the plant, which were taken by the State DEC (*7–9*), gave the following average hourly exposure rates:

1970: 9.8 μR/h
1971: 8.3 μR/h
1972: 8.7 μR/h

Nine Mile Point Nuclear Station Unit 1

Nine Mile Point Nuclear Station Unit 1 is a boiling water reactor with a rated capacity of 1850 MW(t). It is located on the southeast shore of Lake Ontario in the town (township) of Scriba, which has a population of 1400 and Oswego County, which has a population of 23 800. The nearest large city is Syracuse (population 197 300) located 36 miles southeast of the plant. The area in which the plant is located is used primarily for residential and agricultural purposes. Test operations were conducted during the period from late 1969 to March 2, 1970. A long shutdown for maintenance and repairs ended on July 11, 1970. Since July 12, 1970 full power operations have been carried out, subject to maintenance and refueling outages.

Table 9. Radioactivity in algae and/or aquatic vegetation in Lower Hudson

Station	Location from plant	Year	Number of samples	Average concentration[a] (pCi/kg wet weight)						^{40}K (g/kg)
				^{137}Cs	^{60}Co	^{106}Ru	^{95}Zr-Nb	^{54}Mn	^{134}Cs	
Green's Cove	2 miles S	1970	2	232	630	873	333	3751	—	—
		1971	2	811	614	2550	2398	6797	817	4.50
		1972	2	178	43	272	172	263	ND	—
Tappan Zee Bridge, west	14 miles S	1970	2	46	126	335	342	778	—	—
		1971	2	190	146	914	275	1543	—	—
		1972	2	57	70	ND	121	715	—	—
Iona Island	3 miles NW	1970	2	193	81	578	700	341	—	—
		1971	2	289	44	2883	1646	749	56	4.06
		1972	2	128	31	229	150	214	—	—
Peekskill Bay	1.5 miles N	1970	2	189	149	494	799	687	—	—
		1971	2	321	194	ND	120	2422	17	3.73
		1972	2	115	65	154	108	455	—	—

[a] Nondetectable quantities have been considered as 0 pCi/kg for averaging purposes.
ND, nondetectable.
—, no analysis.

Table 10. Radioactivity in fish in the Lower Hudson

Station	Location from plant	Year	Number of samples	Average concentration [a] (pCi/kg wet weight)								
				^{137}Cs	^{60}Co	^{106}Ru	^{95}Zr-Nb	^{134}Cs	^{89}Sr	^{90}Sr	^{65}Zn	^{54}Mn
Green's Cove	2 miles S	1970	3	55	ND	ND	ND	54	—	71	—	70
		1971 [b]	2	286	ND	ND	—	203	ND	140	ND	—
		1972	3	159	ND	ND	—	214	ND	190	—	—
Tappan Zee Bridge, west	14 miles S	1970	2	53	ND	ND	—	33	—	—	—	—
		1971 [b]	2	157	ND	ND	—	149	17	120	ND	—
		1972	2	181	ND	ND	—	84	ND	45	—	—
Iona Island	3 miles NW	1970	2	52	ND	ND	—	15	66	41	—	—
		1971 [b]	3	123	ND	ND	—	56	ND	207	ND	—
		1972	3	159	ND	ND	—	62	ND	34	—	—
Peekskill Bay	1.5 miles N	1970	2	51	ND	ND	—	35	—	90	—	—
		1971 [b]	2	373	ND	ND	—	225	ND	200	ND	—
		1972	3	165	ND	ND	—	80	ND	41	—	—

[a] Nondetectable quantities have been considered as 0 pCi/kg for averaging purposes.
[b] 1971 figures are averaged for flesh and bone composite.
ND, nondetectable.
—, no analysis.

Table 11. Radioactivity in silt in the Lower Hudson River

Station	Location from plant	Year	Number of samples	Average concentration [a] (pCi/kg wet weight)		
				Cesium-137	Cobalt-60	Cesium-134
Green's Cove	2 miles S	1970	2	51	—	—
		1971	2	514	124	441
		1972	—	—	—	—
Tappan Zee Bridge, west	14 miles S	1970	2	41	—	—
		1971	2	892	95	502
		1972	—	—	—	—
Iona Island	3 miles NW	1970	2	25	—	—
		1971	2	385	52	189
		1972	—	—	—	—
Peekskill Bay	1.5 miles N	1970	2	ND	—	—
		1971	2	211	33	119
		1972	—	—	—	—

[a] Nondetectable quantities have been considered as 0 pCi/kg for averaging purposes.
ND, nondetectable.
—, no analysis.

Table 12. Pressurized ionization chamber gamma background survey

Site	Township	1967 (μR/h)	1968 (μR/h)	1969 (μR/h)	1970 (μR/h)
1	Cortlandt	8.8	—	—	9.7
2	Cortlandt	9.2	8.6	8.8	9.5
3	Cortlandt	8.8	7.9	12.4	12.3
4	Cortlandt	10.4	9.8	10.6	10.1
5	Highlands	8.8	9.3	8.5	9.3
6	Cortlandt	9.2	8.9	9.6	8.6
7	Yorktown	9.6	10.1	9.2	10.4
8	Cortlandt	9.2	10.4	9.4	9.6
9	Stony Point	9.2	9.3	8.1	9.1
10	Haverstraw	9.6	10.4	9.2	9.2
11	Clarkstown	8.4	9.4	8.9	8.9
12	Mt. Pleasant	9.2	10.8	10.1	10.1
13	Yorktown	8.1	9.2	8.9	10.1
14	Somers	6.9	8.8	7.7	8.9
15	Kent	9.6	8.5	10.7	10.8
16	Greenburgh	8.4	9.3	9.1	8.6
17	Harrison	9.2	8.9	9.8	9.8
18	Poundridge	9.6	10.1	10.2	11.2
19	North Salem	8.1	—	9.1	10.0

Average reading for all stations near Indian Point Station by year (μR/h)

1964	1965	1967	1968	1969	1970
11.3	10.0	9.0	9.4	9.5	9.8

Liquid waste discharges

Liquid waste from Nine Mile Point Nuclear Station Unit 1 is collected in storage tanks and disposed into Lake Ontario in batches. Discharge is on a daily basis at a controlled rate dependent upon gross beta activity concentrations. The liquid effluent is discharged via the condenser cooling water discharge, which provides dilution. The quantities of radioactive liquid waste discharged by this plant during the years 1969–72 are given in table 13. The composition of a typical batch of radioactive liquid waste is given in table 14.

Gaseous waste discharges

Noncondensible gases generated in the processes of operation of the Nine Mile Point Nuclear Station Unit 1 plant are discharged to the off-gas system by the air ejector. Wastes from this source are held up 30 minutes in order to allow time for the decay of short-lived isotopes. This waste is then discharged to the atmosphere through a stack, 350 feet high. Capability is provided in the system for automatic shutdown in the event that radioactivity release rates exceed a preset limit. The total gaseous activity discharged (*2,17*) and the calculated potential annual dose rates are shown in table 15. A typical isotopic analysis of stack releases is given in table 16 (*17*).

Table 13. Quantities of radioactive liquid waste discharged by the Nine Mile Point Nuclear Station Unit 1

Year [a]	Mixed fission and corrosion products			Tritium		
	Curies released	Annual average concentration (pCi/liter)	Annual average percent limit [b]	Curies released	Annual average percent MPC in discharge canal	Annual average dose from tritium [c] (mrem)
1969	0.90	1.69	1.7	<1	$<10^{-4}$	Negligible
1970	28.0	52.5	52.5	20	1.5×10^{-3}	.006
1971	32.2	60.4	60.4	12.4	9×10^{-4}	.003
1972	34.5	64.6	64.6	28	2.1×10^{-3}	.008
Projected future	2.0	3.75	3.75	20	1.5×10^{-3}	.006

[a] All curies released data except 1972 from reference 2, 1972 and projected future data from draft EIS, reference *17*.
[b] MPC is 100 pCi/liter for unidentified radionuclide mix while technical specifications allow 3300 pCi/liter if isotopic analysis is done.
[c] At plant perimeter, for ingestion of discharge canal water (*16*).

Table 14. Composition of a typical batch of liquid radioactive waste, Nine Mile Point Nuclear Station Unit 1 [a]

Isotope	Half life	Percent in typical batch	Average concentration in discharge canal (pCi/liter)	Percent of MPC
Cobalt-60	5.3 yr	9.5	3.5	0.007
Cobalt-58	71.3 d	15.2	5.6	.006
Chromium-51	27.8 d	60.0	23	.001
Manganese-54	303.0 d	5.9	2.3	.002
Iodine-131	8.0 d	.4	.17	.060
Iron-59	45.0 d	9.0	3.3	.007
Total		100	38	0.083

[a] Normalized to 20 Ci/yr discharge.

Environmental monitoring

Environmental samples taken in the vicinity of the Nine Mile Point Nuclear Station Unit 1 are analyzed for some specific radionuclides and for gross beta (*7–9*). Table 17 gives the results of gross beta analyses of air and water samples. The results are not remarkable. The concentrations in air particulates at the background station in Albany are within the previously mentioned range of nondetectable to 1.08 pCi/m^3. This is true for onsite and offsite samples. The results of water sample analysis are typical for freshwater where the potassium-40 contribution is less significant than in saline water. Again, they fall within the range of background samples taken at Albany which have previously been stated to range from nondetectable to 11 pCi/liter.

Specific radionuclide analyses have not been carried out around the Nine Mile Point Nuclear Station plant to the extent which they are carried out in the vicinity of Indian Point Station. Those samples which have been analyzed include onions and apples from the area (1970), aquatic vegetation and mud from Lake Ontario near the plant (1970) and fish taken near the plant (1971).

Table 15. Release to gaseous effluents from Nine Mile Point Nuclear Station

Year [a]	Noble gases				Halogens and particulates			
	Releases (curies)	Permissible (curies)	Percent of permissible	Annual dose (mrem) from immersion [c]	Releases (curies)	Permissible [b] (curies)	Percent of permissible	Annual average dose (mrem) to infant thyroid [c]
1969	60	2.6×10^7	Negligible	Negligible	<0.001	47.3	Negligible	Negligible
1970	9 500	2.6×10^7	0.04	0.20	<.06	47.3	0.1	0.50
1971	253 000	2.6×10^7	.97	5.3	.78	47.3	1.65	7.5
1972	520 000	2.6×10^7	2.0	10.9	.95	47.3	2.01	9.1
Projected future	11 000	2.6×10^7	.05	.23	.56	47.3	1.18	5.4

[a] Annual releases (except 1972) from reference 2, 1972, and projected future from draft EIS reference *17*.
[b] Permissible limit for multiple release points derived from curies released and sum of percentages of permissible from points of release, see also reference *1*.
[c] Doses are for continuous occupation at worst site location and are hypothetical; representation of a real dose is not intended.

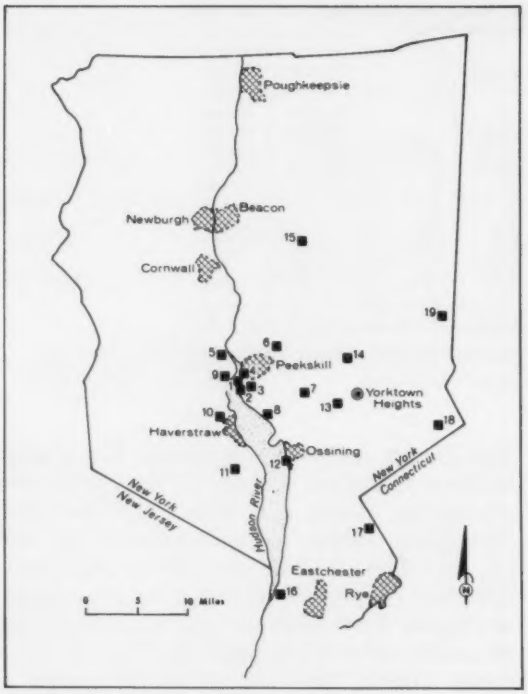

Figure 3. Location of stations for pressurized ionization chamber gamma survey

Small amounts of cesium-137 (28 pCi/kg in one sample) and of strontium-90 (42 pCi/kg in one sample) were observed in apples. The analysis of onion samples indicated small quantities of zirconium-niobium-95 (21 pCi/kg in one sample) and strontium-90 (40 pCi/kg in one sample). These data are insufficient to allow conclusions to be drawn.

Mud samples taken from Dempster Beach showed some cesium-137 (214 and 12 pCi/kg in two samples), ruthenium-106 (203 pCi/kg in one sample) and cesium-134 (41 pCi/kg in one sample). As mentioned previously, cesium-137 and ruthenium-106 are characteristic of weap-

Table 16. Radionuclides in stack discharges, Nine Mile Point Nuclear Station Unit 1

Isotope	Percent total	Discharge rate (μCi/s)[a]
Xenon-138	10.9	860
Krypton-87	18.9	1 490
Krypton-88	16.0	1 260
Krypton-85m	5.5	436
Xenon-135	24.0	1 890
Xenon-133	23.3	1 835
Nitrogen-13	1.4	115
Total	100	7 886

[a] Normalized to 250 000 Ci/yr at 100 percent service availability.

Table 17. Radioactivity levels in air particulates and water (gross beta), Nine Mile Point Nuclear Station Unit 1

Station location		1970 [a]	1971 [a]	1972 [a]
Air particulates (pCi/m³):				
Onsite, 3 stations:	Average	0.19		
	Maximum	.69		
	Minimum	ND		
Scriba:	Average	.12	0.20	0.05
	Maximum	.37	.69	.14
	Minimum	.01	.02	ND
Water concentrations (pCi/liter):				
Oswego City Hall tap, Lake Ontario water	Average	4	4	4
	Maximum	5	5	6
	Minimum	3	3	ND
New Haven, Dempster Lake Road, Lake Ontario water	Average	5	5	5
	Maximum	8	6	6
	Minimum	4	3	4

[a] References *7*, *8*, and *9*, respectively, for 1970–1972 data on offsite stations.

Table 18. Radioactivity in aquatic samples, Nine Mile Point Nuclear Station Unit 1 (pCi/kg)

Sample type	Year		Radionuclide Concentration (pCi/kg wet weight)							
			^{137}Cs	^{60}Co	^{134}Cs	^{65}Zn	^{90}Sr	Gross beta	Gross gamma	^{95}Zr-Nb
Fish:	(Preop) 1969	Maximum	132	14	—	76	510	870	565	
		Minimum	ND	ND	—	ND	76	364	188	
	1970	Maximum	6 190	[a] 630	—	ND	3 160	4 100	7 300	
		Minimum	ND	ND	—	ND	110	—	300	
	1971	Maximum	542	ND	71	ND	[b] 589 (18)	—	—	
		Minimum	190	ND	ND	ND	[b] 433 (3)	—	—	
	1972	Maximum	1 060	90	350	—	[b] (66)	—	—	
		Minimum	206	ND	ND	—	[b] (9)	—	—	
Algae:	(Preop) 1969	Maximum	200	30	—	70	2 410	13	35 600	—
		Minimum	—	—	—	—	—	—	—	—
	1970	Maximum	1 140	15 400	—	ND	—	18 100	35 000	—
		Minimum	ND	1 180	—	ND	150	1 710	—	—
	1971	Maximum	269	19	—	—	—	—	—	994
		Minimum	66	ND	—	—	—	—	—	958
	1972	Maximum	—	—	—	—	—	—	—	—
		Minimum	—	—	—	—	—	—	—	—

[a] This was the only 1 of 13 samples showing any detectable cobalt-60; it may therefore be suspect.
[b] Numbers in parenthesis are for flesh—others are for bone.
ND, nondetectable, below minimum detectable activity.

ons testing fallout. The observed level of cesium-134 is low and no conclusion as to its possible source would be justified.

An aquatic sampling program was conducted around the facility by Eberline Instrument Corporation in 1969 and 1970. Some of the results of that program and more recent results of analysis by the State are given in table 18. Some increases in concentrations of nuclides are evident after 1969, but the extraction of data from different sources and the lack of knowledge concerning how to interrelate information from different analysists makes it difficult to draw further conclusions. The capability of algae to significantly concentrate cobalt-60 is evidenced by this table.

The State DEC reports the following average hourly exposure rates (taken from PIC readings) in the vicinity of the Nine Mile Point Nuclear Station Unit 1 (*7–9*):

1970: 8.1 μR/h
1971: 7.6 μR/h
1972: 7.4 μR/h

R. E. Ginna Nuclear Power Plant

The R. E. Ginna Nuclear Power Plant is located in Brookwood, Wayne County, New York. The site, consisting of 338 acres, is 16 miles east of Rochester, N.Y., which has a population of approximately 500 000. This is a pressurized water reactor rated at 1300 MW(t). The region adjacent to the site is agricultural, with open, rolling terrain. The predominant wind direction is away from Rochester over Lake Ontario (*18*).

Initial criticality was attained in November 1969 and testing continued until May 1970. Since that time the plant has routinely been used for power production except for maintenance and refueling outages. A 17 percent derating occurred in portions of 1972 and 1973 as a result of the identification of unpressurized fuel cladding collapes in Ginna fuel.

Liquid waste discharges

Liquid radioactive wastes from the Ginna plant are discharged at controlled rates to Lake

Table 19. Quantities of radioactive liquid waste discharged by the R. E. Ginna Nuclear Power Plant

Year	Mixed fission and corrosion products				Tritium			
	Curies released [a]	MPC [a] (pCi/liter)	Annual average percent MPC	Annual average dose [b] (mrem)	Curies released [a]	Annual average percent MPC	Annual average dose [b] (mrem)	
1969	0.02	300	0.01	0.05	<1	Negligible	Negligible	
1970	10.0	300	5	25	110	5×10^{-3}	0.03	
1971	.96	300	.5	2.5	154	7×10^{-3}	.04	
1972	.375	300	.18	9	119	5×10^{-3}	.03	
Projected future	.9	300	.5	2.5	<1000	$<5\times10^{-2}$	<.3	

[a] All curies released data from references *2* and *3*, projected future from draft environmental impact statement reference *29*.
[b] For consumption of discharge canal water.

Table 20. Release of gaseous effluents from R. E. Ginna Nuclear Power Plant

Year	Noble and activation gases				Halogens and particulates			
	Releases (curies)	Permissible (curies)	Percent of permissible	Dose [a] (mrem)	Releases (curies)	Permissible (curies)	Percent of permissible	Dose [a] (mrem)
1969	<1	3.6×10^{5}	Negligible	Negligible	0.001	1.7	Negligible	Negligible
1970	10 000	3.6×10^{5}	2.8	5.7	.05	1.7	3.0	15
1971	31 800	3.6×10^{5}	8.9	18.2	.17	1.7	10.0	51
1972	11 800	1.7×10^{5}	6.9	7.0	.035	.9	3.8	11
Projected future	2 350	1.7×10^{5}	1.4	1.4	.11	.9	12.2	33

[a] Noble gas dose, continuous immersion at site boundary skin dose; halogen dose, infant thyroid dose from boundary milk ingestion. Annual releases, except 1972, from reference *2*, 1972 data, *3*.

Ontario, using the once-through-cooling discharge water flow for dilution. The quantities of radioactive materials released in liquid wastes from the Ginna nuclear plant are given in table 19. This plant is notable for its control to the point of virtual elimination of primary-to-secondary leakage and the associated escape of some primary coolant activity into the environment.

Gaseous waste discharges

The off-gases from the reactor coolant make up most of the gaseous radioactive wastes associated with this facility. These gases are held up for at least 30 minutes in order to allow time for decay of radioisotopes with short half lives. The waste is discharged to the atmosphere through various building vents. The total gaseous activity discharged from Ginna in recent years and the hypothetical possible dose are shown in table 20.

Environmental monitoring

Results of gross beta analyses on air particulates and water samples from the vicinity of the R. E. Ginna Nuclear Power Plant are presented in table 21. No overt evidence of effects from operation of the plant are observable from these data.

Various environmental samples, including fish, aquatic vegetation, mud, and grapes have been studied for accumulation of radioactive materials from the Ginna Nuclear Plant (*7–9*). Results of some of these analyses for fish and algae are contained in table 22. With the possible exception of some increase in the small quantities of manganese-54 observed in algae, and the reported observance by the utility of small quantities of cesium-134 in *Cladophora* from the discharge area (*18*), no effects of plant operation are observable.

Analyses of milk samples from the Ginna area have likewise been negative. Only the naturally occurring potassium-40 has been observed in milk.

External pressurized ionization chamber readings taken at the Ginna site boundary by the State DEC gave the following average hourly exposure rates (*7–9*):

1970: 7.3 μR/h
1971: 7.7 μR/h
1972: 7.1 μR/h

Appendix I to 10 CFR Part 50

On December 3, 1970 the Atomic Energy Commission published in the Federal Register (35 F.R. 18385) amendments to 10 CFR Part 50 that specified design and operating requirements for nuclear power reactors to keep levels

Table 21. R. E. Ginna Nuclear Power Plant gross beta radioactivity levels in air particulates and water

Station		Air concentration (pCi/m³)		
		1970	1971	1972
Ontario:	Maximum	.048	0.08	0.18
	Minimum	.04	.04	ND
	Average	.18	.22	.07

Station		Water concentrations (pCi/liter)								
		1970			1971			1972		
		Gamma	Beta	Tritium	Gamma	Beta	Tritium	Gamma	Beta	Tritium
Ontario:	Maximum	—	5	—	(*)	6	1 040	—	8	940
	Minimum	—	3	—	(*)	2	ND	—	ND	ND
	Average	—	4	—	(*)	4	ND	—	4	ND

* No discernible photopeaks.
ND, nondetectable.

Table 22. Radioactivity in biota in Lake Ontario near R. E. Ginna Nuclear Power Plant

Station	Year	Number of samples		Average concentration (pCi/kg wet weight)				
				^{137}Cs	^{134}Cs	^{60}Co	^{89}Sr [a]	^{90}Sr [a]
Fish samples								
Brookwood	1970	12	Maximum	284	ND	ND	152	3516
			Minimum	55	ND	ND	—	89
Brookwood	1971	9	Maximum	528	12	ND	29	507
			Minimum	106	ND	ND	ND	365
1000 feet offshore	1971	7	Maximum	345	ND	ND	—	996
			Minimum	169	ND	ND	—	161
Brookwood	1972	15	Maximum	737	ND	ND	ND	3900
			Minimum	ND	ND	ND	ND	1900 (2 samples)

Station	Year	Number of samples	Average concentrations (pCi/kg wet weight)						
			^{131}I	^{137}Cs	^{60}Co	^{106}Ru	^{95}Zr-Nb	^{90}Sr	^{54}Mn
Algae samples									
Water filtration plant	1970	2	681	240	ND	309	1834	279	ND
	1971	1	—	269	19	685	958	—	85
	1972	—	—	—	—	—	—	—	—
On the lake	1970	2	—	307	15	840	1719	71	20
	1971	1	—	66	ND	667	994	—	91
	1972	—	—	—	—	—	—	—	—

[a] Strontium-89 and strontium-90 values are bone concentrations.
ND, nondetectable, below minimum detectable activity.

of radioactivity in effluents to unrestricted areas as low as practicable. No numerical criteria or guidance were provided. Now, as specified in its notice of proposed rulemaking published in the Federal Register of June 9, 1971 (Vol. 36, No. III) the AEC has under consideration further amendments to 10 CFR 50 in the form of a new Appendix I. This amendment would provide numerical guides for meeting the "as low as practicable" criteria.

Briefly summarized, the proposed Appendix I provides the following:

1. For liquid releases except tritium; a limit of 5 Ci/yr per reactor and an annual average concentration not to exceed 20 pCi/liter prior to entering a natural body of water.
2. For tritium; an annual average concentration not to exceed 5000 pCi/liter prior to entering a natural body of water.
3. For gaseous releases, a dose from all reactors at a site not to exceed 10 mrem/yr at any point on the site boundary or any offsite location.

The above mentioned release limits may be exceeded provided that:

1. Maximum exposure to the whole body or any organ except the thyroid of any offsite individual due to all liquid radioactive effluent releases from a site does not exceed 5 mrem/yr.
2. Maximum exposure to the whole body or any organ except the thyroid of any offsite individual due to all gaseous radioactive effluent releases from a site does not exceed 5 mrem/yr.
3. Maximum thyroid exposure is limited to 15 mrem/yr.

This regulation is to be directed solely at light-water reactors used in the production of electric power. The AEC retains the right to set lower release limits on a case-by-case basis if it desires and if operation within the regulations already described may result in the dose to the whole body or any organ except the thyroid of any offsite individual, from all sources on a site, in excess of 5 mrem/yr, or 15 mrem/yr for the thyroid.

As has been indicated, this amendment is still under consideration at the time of preparation of this report. Facilities operating prior to its adoption will be required to meet the criteria discussed above by developing, within 36

months of the effective date of the regulations, technical specifications which will assure compliance.

All operating and proposed nuclear-electric generating facilities in New York, in anticipation of adoption of Appendix I, have begun or continued programs which are expected to comply with Appendix I. In some cases, this has necessitated design changes or addition of waste treatment capability. Compliance would therefore be expected from operating facilities well before the passing of 36 months. Those release quantities indicated in tables 6, 7, 13, 15, 19, and 20 under "projected future" are those anticipated to comply with this new limitation.

Nuclear Fuel Services, Inc.

Nuclear Fuel Services, a subsidiary of Getty Oil Company, started operations in 1966 as a spent fuel reprocessing plant in the town of Ashford, Cattaraugus County. The site is located about 30 miles south of Buffalo. Original design capacity was 300 tons of nuclear fuels per year or about one ton per day. The plant is equipped with an ion exchange system and a lagoon system for maintaining control of low-level liquid waste discharges. Gaseous radioactive wastes are discharged through a 200-foot stack.

The land within 25 miles of the plant is used primarily for agricultural purposes. The greatest population densities are toward Buffalo, northwest of the site. The approximate population within 10 miles of the site is 15 700.

Liquid waste

Liquid waste is discharged at a controlled rate into Frank's Creek, which flows into Buttermilk Creek and then to Cattaraugus Creek before leaving the site. Cattaraugus Creek flows to Lake Erie. There are no public drinking water supplies on any of the creeks, but Lake Erie is used as a public water supply for several municipalities, including Buffalo.

The effluent discharge rate of the plant is normally about 200 000 gallons per day. The treatment system originally consisted solely of a lagoon network for treatment of low-level liquid wastes. In May 1971, additional treatment capability in the form of a precipitation and ion exchange plant was added to the system. It is the intent of this plant to reduce concentrations of all radionuclides, except tritium, to below MPC_w (from Atomic Energy Commission's 10 CFR 20 regulation) at the point of discharge from the final holding lagoon (*20*). The lagoon network consists of two 22 000 gallon interceptors, one 300 000 gallon lagoon and two 2.3 million gallon lagoons. These lagoons provide hold-up capability of up to about 100 days, with the average being about 1 month. Prior to installation of the additional treatment facilities, NFS operated under a provisional license which limited discharges such that gross beta radioactivity in the local offsite waters (Cattaraugus Creek) was less than 150 pCi/liter.

High level liquid wastes (ca 400 gallons/tonne U) are stored onsite in vented underground steel vaults which are monitored for leakage.

NFS ceased operations in December 1971 and

Table 23. Radioactive liquid releases from Nuclear Fuel Services Reprocessing Plant [a]

Year	Radioactivity concentrations (curies)										
	Gross beta	Gross alpha	^{3}H	^{90}Sr	^{89}Sr	^{129}I	^{137}Cs	^{134}Cs	^{106}Ru	^{238}Pu	^{239}Pu
1967	31.0	0.056	4204	9.86	[b] NA	0.07	NA	NA	NA	NA	NA
1968	46.4	.139	2646	5.03	NA	.028	NA	NA	NA	NA	NA
1969	136.2	.018	5975	10.07	NA	.2	NA	NA	NA	NA	NA
1970	87.0	.105	4516	14.2	NA	.341	NA	NA	NA	NA	NA
1971	77.1	.046	3854	6.63	2.27	.211	10.02	1.83	48.2	4.2×10^{-3}	4.8×10^{-3}
1972	42.74	.026	600	.68	.077	.055	1.1	.185	6.11	7.0×10^{-4}	5.3×10^{-4}

[a] Release data from Quarterly Reports, reference *20*.
[b] NA, not available.

has not processed fuel since that time. Cleanup and decontamination in preparation for construction of additional throughput capacity have been carried out. The resumption of operations at the old capacity or at some expanded capacity is not expected until about 1979. A record of historical releases of liquid wastes is presented in table 23.

Gaseous waste discharge

Gaseous wastes are discharged to the environment via a 200-foot stack. Because of the long decay times prior to dissolution (150 day minimum—usually significantly longer) the only radioactive noble gas of significance is krypton-85. Some small amounts of iodines and particulates are also present, as is tritium. Krypton-85, tritium, and iodine-129 released in gaseous effluents have all been subject to various studies around NFS (*21–23*). Iodine-129 in particular has come under careful scrutiny recently by the State Department of Environmental Conservation (*24*). The amounts of gaseous radioactive effluents released from NFS in recent years is presented in table 24 (*20*).

Environmental monitoring

The NFS facility, because it is the first privately owned commercial fuel reprocessing plant in the United States, has been the object of some of the most extensive scientific evaluations carried out in the environmental radiation field. Preoperational environmental analyses began at the site in 1964 and routine post-operational monitoring has been carried out by several agencies since reprocessing commenced. In addition, many specialized specific studies have been conducted by various interested groups and organizations. The graphs in figures 4 through 10 show the changes observed since 1967 in various environmental radiation parameters. These data are reported by NFS as the results of its own monitoring programs (*25*). The graphs are self-explanatory but a few particular observations might be mentioned here.

First, the onsite gross beta activity in air is usually fractionally higher than the offsite average. A generally decreasing trend is observed, particularly since mid-1971, in both alpha and beta concentrations in air.

Levels for gross beta, strontium-90 and tritium in Cattaraugus Creek are observed to have increased significantly above preoperational background levels in the late 1960's, then decreased somewhat since 1970 levels.

Gross beta and alpha activity in silt taken from Cattaraugus or Buttermilk Creeks both show increases from 1967 levels with decreases following mid-1971. Concentrations of gamma-emitting nuclides, particularly cesium-137 and ruthenium-106, are of sufficient concentrations on creek bottoms and banks in the immediate

Table 24. Radioactive gaseous releases from Nuclear Fuel Services Reprocessing Plant

Year	Radioactivity concentration (curies)						Total fuel processed (tons)
	^{85}Kr	^{3}H	^{131}I	^{90}Sr	^{89}Sr	^{106}Ru	
1967	327 000	[a] 500	<0.06	[b] 0.483			136.5
1968	110 000	500	6.6×10^{-3}	[b] 1.07			139.0
1969	[c] 360 000	500	<.03	[b] .119			120.3
1970	[c] 625 000	500	<.03	[b] .187			NA
1971	220 800	1 070	2.4×10^{-3}	3.57×10^{-4}	2.73×10^{-4}	1.32×10^{-3}	68.8
1972	No dissolutions	5.47	$.96\times10^{-3}$	4.12×10^{-3}	2.1×10^{-3}	2.94×10^{-2}	None

[a] 1967 to 1970 tritium releases as estimated, reference *23*.
[b] Gross beta on total particulates.
[c] Estimated using one half the reported monthly maximum percent release limits for entire month's operation.
NA, not available.
Release limits: particulates—0.1 μCi/s
iodine—3.3 Ci/yr
krypton-85—12 600 Ci/day.

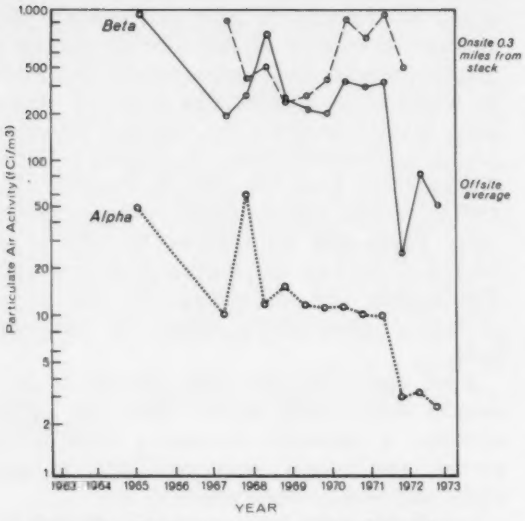

Figure 4. Air activity at site perimeter stations

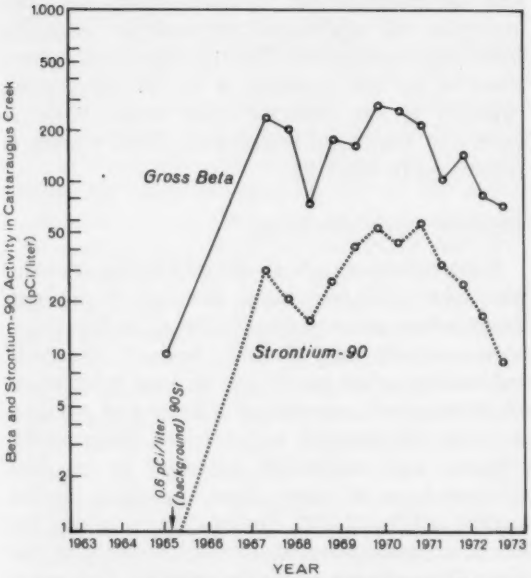

Figure 6. Gross beta and strontium-90 activity in Cattaraugus Creek, downstream

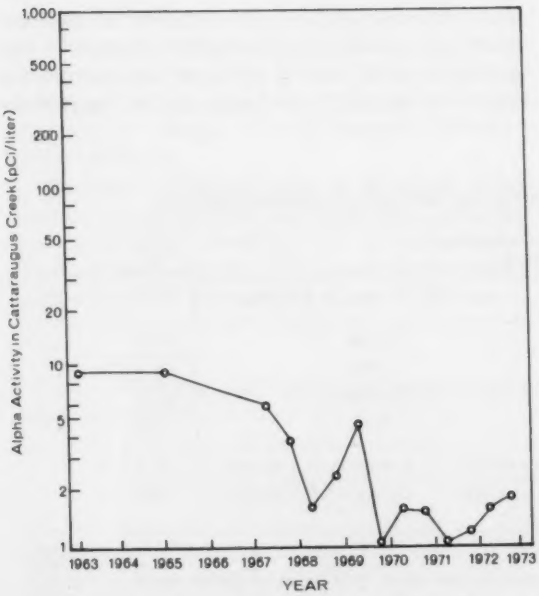

Figure 5. Alpha radioactivity in Cattaraugus Creek, downstream

Figure 7. Tritium activity in Cattaraugus Creek, downstream

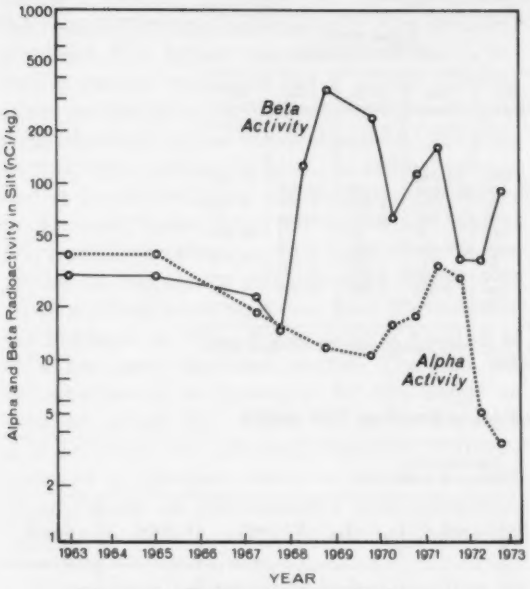

Figure 8. Radioactivity in silt from Cattaraugus Creek

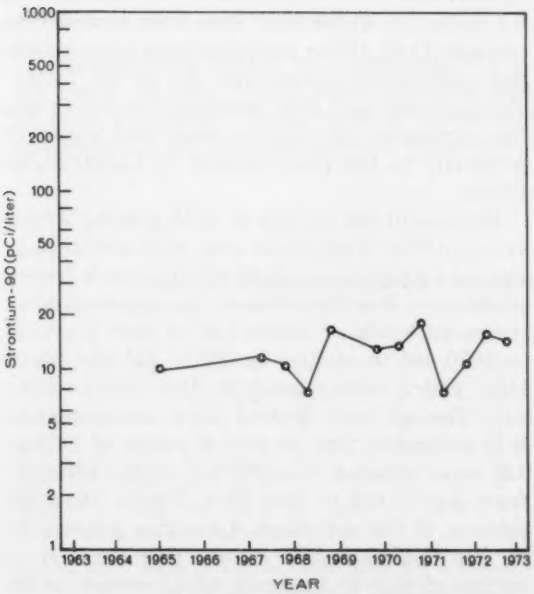

Figure 9. Strontium-90 in milk from NFS farm

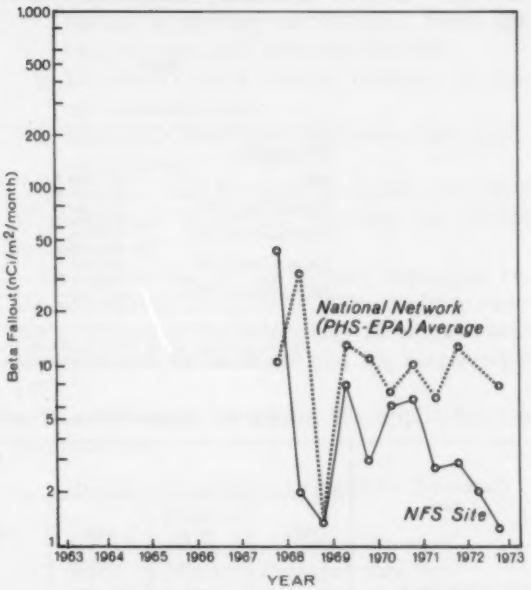

Figure 10. Beta radioactivity in fallout

vicinity of the site to effect changes in dose readings above the creek when water flow is down. Such concentrations are variable subject to pH of the water, reproducibility in sampling, and scouring by high water flow.

The milk from the NFS farm showed relatively stable concentrations of strontium-90 at a level less than 10 percent of allowable FRC limits for populations. This level is comparable to the level of strontium-90 in other milk samples in the EPA network. No iodine-131 above the minimum detectable activity of 10 pCi/liter has been detected.

The fallout sampling station on the site has reported levels somewhat paralleling and consistently lower than the Environmental Protection Agency national network average.

Two biological species which have elicited interest at NFS are deer and fish (*26*). Both have been suggested as the possible pathway of concern for the "maximum" individual. Concentrations of radionuclides in fish and deer from the NFS area are given in tables 25 and 26. Both averages and maximum observed concentrations are given for fish whereas only maximum observed concentrations are listed for deer.

Table 25. Concentrations of radionuclides in fish from NFS vicinity

Date		Concentration (pCi/kg wet weight)				
		^{90}Sr (flesh)	^{90}Sr (bone)	^{134}Cs (flesh)	^{137}Cs (flesh)	^{3}H [b] (flesh)
Fish samples:						
1970	Average [a]	3 630	15 400	—	—	21 000
	Maximum [a]	14 500	620 000	5 890	34 800	—
January-June 1971	Average	280	6 300	2 100	6 900	9 500
	Maximum	280	18 500	2 100	6 900	—
July-December 1971	Average	660	—	10	71	46 000
	Maximum	660	290 000	301	1 670	—
January-June 1972	Average	80	740	700	1 500	7 700
	Maximum	6 900	25 000	1 264	6 104	—
July-December 1972	Average	260	1 340	540	2 300	7 200
	Maximum	1 710	—	—	—	—

[a] Average reported by NFS, maximum from NFS or DEC data on rough fish obtained onsite.
[b] Equilibrium with water concentration is assumed.

Table 26. Concentrations of radionuclides in deer from NFS vicinity

Date	Concentration (pCi/kg wet weight)								
	^{137}Cs	^{134}Cs	^{60}Co	^{106}Ru	^{89}Sr	^{90}Sr	^{65}Zn	^{239}Pu	^{129}I in thyroid (pCi/g)
Deer samples [a]									
1970	4 687	784	56	ND	7	28	107	—	3 700
1971	1 428	314	—	108	—	10	232	0.72	1 400
1972	356	65	ND	ND	ND	30	142	1.90	360

[a] All values are maximums reported by DEC in muscle tissue; iodine-129 in thyroids.
ND, nondetectable.

Comparisons between data on fish concentrations at NFS and those at other facilities readily illustrate that much larger concentrations of nuclides are occurring near the NFS site. This is due both to the slightly larger releases which were taking place at NFS and to the much smaller dilution flows available. Consumption of 4.3 kg annually of fish containing radionuclide concentrations reported in 1971 would result in 1.3 mrem/yr whole body dose from radioactive cesiums and 1.2 mrem/yr bone dose from strontium-90 (*16*).

Background deer samples taken near Albany by the State DEC in 1970 showed no observable radionuclides in four specimens, except for cesium-137, which may be associated with fallout (*7*). Maximum observed concentration of cesium-137 was 140 pCi/kg, which is significantly less than the 4687 pCi/kg observed in one NFS sample. Recalling that fallout at NFS is consistently below the national average points to the conclusion that the NFS facility is the source of this radionuclide in this case. Consumption of 4.8 kg annually of deer meat containing the average concentrations reported in 1971 has been calculated to correspond to a 0.4 mrem/yr whole-body dose from radioactive cesiums (*16*). Other investigations have identified individuals consuming up to 50 kg/yr. For both fish and deer consumption pathways, the population at risk is small and confined primarily to the near vicinity of Cattaraugus Creek.

Because of the system of milk pooling which exists in New York State area, milk contamination by radioiodines might affect a much larger population. For this reason, the appearance of increased levels of iodine-129 in deer thyroids in 1970 led to studies by EPA and the State DEC which concentrated on this nuclide (*22–24*). Though only limited data are available, it is estimated that about 0.9 curies of iodine-129 were released from NFS in liquid effluents from April 1966 to July 1971. This is about 20 percent of the estimated 4.4 curies present in all the fuel processed during this time. It is estimated that a minimum of 1.1 curies or 25 percent of the iodine-129 in the fuel was re-

leased in gaseous effluents. During this period, the removal system consisted only of a chemical scrubber. For future operations, NFS will install a caustic scrubber and a highly efficient silver zeolite absorber. The studies indicate that such improved iodine removal systems are warranted, since iodine-129 levels in animal species and in the environment reached 10^3 or 10^4 times background levels. Also, iodine-129 was identified in milk samples (up to 2.1 pCi/liter) in the period of November 1971 through May 1972, when animals were on stored feed harvested in the summer of 1971. No long-term buildup in milk has been identified as yet. The half life by weathering is probably in the range of that of iodine-131, which is 12 to 20 days, and secretion into the milk once the iodine is ingested by the cow occurs in less than 1 day. Root uptake or resuspension and adsorption have not visibly contributed to iodine-129 reaching the food chain.

Pressurized ionization chamber readings by the State DEC gave the following average hourly exposure rates (*7–9*):

1970: 9.3 μR/h
1971: 8.6 μR/h
1972: 8.4 μR/h

Brookhaven National Laboratory

Brookhaven is located on a 5265 acre site in the center of Long Island, about 60 miles east of New York City. Three types of operations contribute to the local background. These are:

a. Gaseous and particulate radioactivity contained in cooling air effluent from the two reactors and from the hot lab,
b. Low-level liquid waste releases to the environment, and
c. Radiation from two multicurie field gamma sources.

Of these, a and b, result in small quantities of radioactive materials reaching the offsite environment.

The quantities of radioactive materials released in liquid and gaseous effluents from various activities at the laboratory in recent years are indicated in tables 27 and 28, respectively (*27*).

The following acronyms are applicable for Brookhaven:

BGRR—Brookhaven Graphite Research Reactor
HFBR—High Flux Beam Reactor
MRR —Medical Research Reactor
MRC —Medical Research Center

Environmental monitoring

Brookhaven National Laboratory has monitored various environmental media for several years (*28*). Recently, the State DEC has also done environmental monitoring. The DEC has annually analyzed milk and river water samples from the vicinity since 1970. In addition, special samples such as ducks (in 1970), clams (1970) and harbor seal (1971) have been analyzed. Small amounts of radio-nuclides

Table 27. Radioactive materials discharged in liquids from Brookhaven National Laboratory [a]

Year	^{3}H (Ci)	Quantity (mCi)								
		Gross beta	^{7}Be	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr-Nb	^{131}I	^{137}Cs	^{144}Ce
1967	12.4	54.9								
1968	20.5	22.0								
1969	18.2	20.8								
1970	35.6	29.1								
1971	11.8	31.9								
1972	6.32	35.6	2.53	0.27	0.42	5.11	0.51	5.91	11.02	6.79

[a] All contaminated flow passes through sand filter beds where approximately 15 percent passes into the ground water and 85 percent to the Peconic River. During 1972 of the Peconic River flow 45 percent went to ground water before leaving the laboratory perimeter and 55 percent went downstream. Thus, on the average, only 47 percent of the effluent flow ends up downstream. This same fraction of tritium would have ended up downstream but because of varying chemical differences, carryover fractions differ slightly for other nuclides. Since these fractions are influenced by stream flow rates, the amounts indicated are the total of the input to the Peconic River and that passing to ground water onsite.

Table 28. Radioactive gaseous discharges Brookhaven National Laboratory

Source	Gaseous tritium [a] releases (Ci)			
	1969	1970	1971	1972
BGRR [b]	(376	—	—	—
HFBR	total)	681	434	602
MRR	—	—	—	—
MRC	—	—	0.16	9.12
Chemistry	—	—	12.3	18.3
Van de Graaff	—	—	95.2	276.8
Total	376	681	541.7	906.2
	Argon-41 release (Ci)			
BGRR	193 000	—	—	—
MRR	1 480	1 347	556	605

[a] All as tritiated water vapor except 7.14 Ci in 1971 and 216.0 Ci in 1972 as gas from the Van de Graaff.
[b] In addition, 12.0 mCi of gross beta particulates and 6.8 mCi of iodine-131 were discharged in 1969 while the BGRR was still in operation.

characteristic of weapons test fallout were sometimes detected, but no isotopes attributable to operations of Brookhaven have been found (*7–9*).

Table 29 gives tritium amounts and concentrations in the Peconic River at the boundary of Brookhaven over the past few years. Large fluctuations are apparently due to variations in activities at the laboratory. The principal source of tritium is operation of the waste evaporator, which currently produces about 150 mCi per operating day in about 1500 gallons of condensate. This has increased over the years roughly proportionately to the DTO concentration in primary coolant of the High Flux Beam Reactor. Production of tritium from this source was about 50 mCi per operating day in early 1969 compared to 150 mCi in 1972.[3]

Table 30 provides data for the same years (1969–1972) for radionuclide concentrations in precipitation and in milk from the dairy nearest BNL. As indicated, the State Department of Environmental Conservation began analyzing milk samples from this dairy in the second quarter of 1970. Besides strontium-90, the DEC analyzes for iodine-131, cesium-137, strontium-89, and tritium. The reported results for cesium-137 are about the same as those given by analyses at BNL. Iodine-131, strontium-89, and tritium concentrations have, on the average, been below detectable limits.

The precipitation data demonstrate the seasonal pattern of transfer of fallout materials from the stratosphere, generally being at a maximum in late spring or early summer.

The concentration of strontium-90 in milk from the nearest dairy was among the highest reported anywhere in New York State in 1972, averaging 16 pCi/liter. Such diverse locations as Cattaraugus County, Erie County, and Oswego County gave results of 15, 15, and 13 pCi/liter, respectively, so that the concentrations at this location were not anomalously

[3] Memorandum from A. P. Hull to C. B. Meinhold re: tritium concentrations in the Peconic River, Brookhaven National Laboratory.

Table 29. Tritium amounts and concentrations at BNL perimeter, Peconic River samples, 1969 to 1972

Date	1969		1970		1971		1972	
	Amount (Ci)	Concentration (nCi/liter)	Amount (Ci)	Concentration (nCi/liter)	Amount (Ci)	Concentration (nCi/liter)	Amount (Ci)	Concentration (nCi/liter)
January	0.1	2	0.3	3	0.7	*11	0.01	2
February	.1	2	1.1	*12	.3	*5	.01	1
March	.3	5	6.4	*75	.4	*4	.03	1
April	.1	2	1.6	*10	.4	*5	.1	*2
May	.7	10	3.5	*22	.5	*7	.08	1
June	.3	*4	3.7	*30	.7	*28	.07	1
July	.4	*16	2.0	*19	.04	*6	.2	1
August	.6	*7	1.5	*14	.02	*4	.03	1
September	.1	2	.4	*18	.02	*3	.03	*2
October	1.4	*34	.6	*18	.02	*3	.3	*13
November	.8	*14	.2	*4	.01	2	.4	*7
December	.5	*6	.3	*7	.01	1	1.1	*7
Total	5.4		21.6		3.1		2.4	
Average		9		19		8		3

* Months during which evaporator was operated.

Table 30. Comparison of fallout-related levels in precipitation and milk in BNL area, 1969 to 1972

Month	1969				1970				1971				1972			
	Precipitation (nCi/m²)		Milk from nearest dairy (pCi/liter)		Precipitation (nCi/m²)		Milk from nearest dairy (pCi/liter)		Precipitation (nCi/m²)		Milk from nearest dairy (pCi/liter)		Precipitation (nCi/m²)		Milk from nearest dairy (pCi/liter)	
	Gross beta	^{90}Sr	^{137}Cs	^{90}Sr	Gross beta	^{90}Sr	^{137}Cs	^{90}Sr	Gross beta	^{90}Sr	^{137}Cs	^{90}Sr	Gross beta	^{90}Sr	^{137}Cs	^{90}Sr
Jan	0.98	0.02	19		1.0	0.03			1.57	0.04	18		2.39	0.05	12	
Feb	1.97	.06	—		2.3	.05		—	2.34	.12	24	10	1.90	.07	16	13
Mar	7.27	.15	—		5.8	.21			4.95	.17	14		2.56	.11		
Apr	9.26	.15	10	—	5.5	.18	18		4.59	.05	10		15.87	.11	15	
May	10.74	.06	19	—	9.9	.21	12	10	14.03	.30	20	5	6.78	.08		7
June	8.67	.10	19	—	10.4	.18	27		4.39	.27	20		7.41	.10		
July	13.29	.12	8	—	15.4	.24	28		2.70		15		1.40	.02	17	
Aug	7.12	.12	20	—	8.7	.17	38	17	2.53	.13	22	11	.16	(a)		21
Sept	3.52	.06	10	—	1.0	.07	28		.38	.05	20		.40	.11		
Oct	11.30	.04	5	—	1.5	.05	27		1.25	.14	22		.85	.03	14	
Nov	2.90	.06	10	—	4.2	.11	20	13	4.75	.11	14	10	.82	(a)		NA
Dec	5.04	.14	—	—	2.0	.06	33		4.77	.05	11		.95	(a)		
	83.16	1.12		—	67.7	1.56			46.67	1.43			44.49	0.81		
			[b] 13	—			[b] 26 [c] 28	[c] 14			[b] 18 [c] 28	[c] 9			[b] 16 [c] 17	[c] 16

[a] Information not available.
[b] Measurements by Brookhaven National Laboratory.
[c] Measurement by Department of Environmental Conservation.
NA, no analysis.

large and not conclusively contributable to any operations at BNL.

External PIC readings were taken around BNL in 1970. The average reported dose rate of 7.3 μR/h was the lowest in the State along with the same value reported around the Ginna reactor (*7*).

Conclusion

As a means of making some evaluation of the cumulative impact of all the facilities, the total yearly discharges for all of those discussed here have been compiled in table 31. Then, by taking population exposures (man-rem within 50

Table 31. Total radioactive effluent discharges from major nuclear facilities in New York State

Facility	Liquid releases (Ci)				Noble gas releases (Ci)			
	1969	1970	1971	1972	1969	1970	1971	1972
Indian Point Station Unit 1	28	7.8	81	25.4	600	1 800	380	543
Nine Mile Point Nuclear Station Unit 1	.9	28	32.2	34.5	60	9 500	253 000	520 000
R. E. Ginna Nuclear Power Plant	.02	10	.96	.38	<1	10 000	31 800	11 800
Nuclear Fuels Service	136.2	87	77.1	42.8	360 000	625 000	220 800	—
Brookhaven	.01	.02	.01	.04	194 480	1 347	556	605
Total	165	133	191	103	555 140	647 647	506 536	532 948
	Tritium in liquids (Ci)				Airborne halogens and particulates [a] (Ci)			
	1969	1970	1971	1972	1969	1970	1971	1972
Indian Point Station Unit 1	1 000	410	725	574	0.025	0.075	0.21	0.93
Nine Mile Point Nuclear Station Unit 1	<1	20	12.4	28	<.001	<.06	.78	.95
R. E. Ginna Nuclear Power Plant	<1	110	154	119	.001	.05	.17	.035
Nuclear Fuels Sevices	5 975	4 516	3 854	600	.12	.19	.007	.074
Brookhaven	5.4	21.6	3.1	5.9	.021	[b]	[b]	[b]
Total	7 082	5 078	4 749	1 327	0.168	0.375	1.17	1.99

[a] Excludes 1.1 Ci iodine-129 released from NFS in 1966 through 1972.
[b] Insignificant.

Table 32. Population exposures within 50 miles of nuclear facilities in New York State [a]

Location	Dose from liquid releases (man-rem)			
	1969	1970	1971	1972
Indian Point Station Unit 1	2.3	0.6	6.5	2.0
Nine Mile Point Nuclear Station Unit 1	.41	12.8	14.7	15.7
R. E. Ginna Nuclear Power Plant	2.4×10^{-3}	1.2	.12	.05
Nuclear Fuels Services	37.7	27.2	23.5	6.0
Brookhaven	.015	.03	.015	.06
Totals	40.4	41.8	44.8	23.7
	Dose from gaseous releases (man-rem)			
Indian Point Station Unit 1	1.7	5.0	1.1	1.6
Nine Mile Point Nuclear Station Unit 1	1.5×10^{-3}	.24	6.3	13.0
R. E. Ginna Nuclear Power Plant	3.4×10^{-4}	3.4	10.5	4.0
Nuclear Fuels Services	1.6	2.8	1.0	.0
Brookhaven [b]	.03	.05	.04	.05
Total	3.3	11.5	18.9	18.6

Year	Dose (man-rem)		
	Liquid	Gaseous	Total
1969	40.4	3.3	43.7
1970	41.8	11.5	53.3
1971	44.8	18.9	63.7
1972	23.7	18.6	42.3
Total	150.7	52.3	203.0

[a] The doses include all pathways for the given media.
[b] Primarily from airborne tritium (906 curies in 1972).

miles) reported in the literature or an environmental impact statement for the facilities, and by ratioing the reported release quantities in these reports to those given in this report for the various years, table 32 was compiled. This table gives the man-rem exposure total by gaseous or liquid release within 50 miles of each facility (*11,17,19,26,28,29*).

Because of possible changes in nuclide constituency with release quantities, direct ratioing in this manner is not strictly legitimate. Errors encountered in this usage would not be expected to exceed an order of magnitude. It is therefore possible to conclude that the population dose to citizens of New York during the period examined by this study was less than 500 man-rem per year and, due to the conservatism of the assumptions, probably less than 50 man-rem. For comparisons, it may be noted that a population of 20 million persons might be expected to incur on the order of 4 million man-rem per year from other sources, natural and medical, if we assume these other sources to average 200 mrem per person per year. As a further comparison, the total man-rem exposure at a single facility (Nine Mile Point Nuclear Station Unit 1) incurred by employees and visitors has ranged from 1.82 in 1969 to 285.5 in 1972 (*30*).

Acknowledgment

Personal thanks are expressed to Mr. C. Weaver and C. Robbins, FOD, EPA for providing initial data and draft reports and Mr. Weems Clevenger, Director, Environmental Programs Division, EPA Region II for guidance and direction in the early stages of this report.

Special thanks are extended to Ms. Sonia Aronson for her diligent efforts in preparing the original manuscript.

REFERENCES

(1) U.S. ATOMIC ENERGY COMMISSION. Report on releases of radioactivity from power reactors in effluents during 1970. AEC, Division of Compliance, Washington, D.C. (October 1971).

(2) U.S. ATOMIC ENERGY COMMISSION. Report on releases of radioactivity in effluents from nuclear power plants for 1971. AEC, Directorate of Regulatory Operations, Washington, D.C. (August 1972).

(3) U.S. ATOMIC ENERGY COMMISSION. Report on releases of radioactivity in effluents and solid waste from nuclear power plants for 1972. AEC, Directorate of Regulatory Operations, Washington, D.C. (August 1973).

(4) BUREAU OF RADIOLOGICAL HEALTH. Radioactive waste discharges to the environment from nuclear power facilities, BRH/DER 70–2. DHEW, Bureau of Radiological Health, Rockville, Md. 20850 (September 1971).

(5) LOGSDON, J. E. Radioactive waste discharges to the environment from nuclear power facilities. Radiat Data Rep 13:117–130 (March 1973).

(6) LOGSDON, J. E. and J. W. HICKEY. Radioactive waste discharges to the environment from a nuclear fuel reprocessing plant. Radiol Health Data Rep 12:305–312 (June 1971).

(7) BENTLEY, W. and D. METZLER. Annual report of environmental radiation in New York State, 1970. State of New York, Department of Environmental Conservation (August 1971).

(8) BENTLEY, W. and D. METZLER. Annual report of environmental radiation in New York State, 1971. State of New York, Department of Environmental Conservation (August 1972).

(9) BENTLEY, W. and D METZLER. Annual report of environmental radiation in New York State, 1972. State of New York, Department of Environmental Conservation (August 1973).

(10) KELLEHER, W. J. and E. J. MICHAEL. Low level radioactive waste burial site inventory for the West Valley site, Cattaraugus County, N.Y. New York State, Department of Environmental Conservation (June 20, 1973).

(11) U.S. ATOMIC ENERGY COMMISSION. Final environmental statement for Indian Point Nuclear Generating Plan Unit No. 2. Atomic Energy Commission, Directorate of Licensing (September 1972).

(12) TEDFORD, J. E. and R. L. BANGART. Environmental measurements around Consolidated Edison's Indian Point Power Reactor. Atomic Energy Commission, Division of Compliance, Independent Measurements Program (July–December 1970).

(13) DEPARTMENT OF ENVIRONMENTAL CONSERVATION. Environmental and postoperational survey for radioactivity—Consolidated Edison Indian Point Reactors. New York State, Department of Environmental Conservation (September 1971).

(14) BLANCHARD, R. L. and B. KAHN. Pathways for the transfer of radionuclides from nuclear power reactors through the environment to man. Environmtal Protection Agency, Research Division, Cincinnati, Ohio.

(15) LENTCH, J. W., M. D. WRENN, T. J. KNEIP, and M. EISENBUD. Manmade radionuclides in the Hudson River estuary. Institute of Environmental Medicine, New York University Medical Center (November 1970).

(16) OFFICE OF RADIATION PROGRAMS. Environmental radioactivity surveillance guide, ORP/SID 72–2. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C. 20460 (June 1972).

(17) U.S. ATOMIC ENERGY COMMISSION. Draft environmental statement for the Nine Mile Point Nuclear Station Unit 1. Atomic Energy Commission, Directorate of Licensing (July 1973).

(18) ROCHESTER GAS AND ELECTRIC CORPORATION. R. E. Ginna Nuclear Power Plant Unit No. 1, environmental report, Atomic Energy Commission, Directorate of Licensing (August 1972).

(19) U.S. ATOMIC ENERGY COMMISSION. Final environmental statement for Indian Point Nuclear Generating Plant Unit No. 2. Atomic Energy Commission, Directorate of Licensing (September 1972).

(20) DUCKWORTH, J. P. Quarterly reports. West Valley Reprocessing Plant, Nuclear Fuel Services, Inc. (January 1970 through December 1972).

(21) COCHRAN, J., D. SMITH, P. MAGNO, and B. SHLEIEN. An investigation of airborne radioactive effluent from an operating nuclear fuel reprocessing plant, BRH/NEHRL 70–3. DHEW, Northeastern Radiological Health Laboratory, Winchester, Mass. 01890 (July 1970).

(22) MAGNO, P., T. C. REAVEY, and J. C. APIDIANAKIS. Iodine-129 in the environment around a nuclear fuel reprocessing plant, ORP/SID 72–5. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C. 20460 (October 1972).

(23) COCHRAN, J. A., W. R. GRIFFIN, Jr., and E. J. TROIANELLO. Observation of airborne tritium waste discharge from a nuclear reprocessing plant, EPA/ORP 73–1. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C. 20460 (February 1973).

(24) BROOKHAVEN NATIONAL LABORATORY. Brookhaven National Laboratories semiannual reports on environmental levels of radioactivity, 1967–1971. Brookhaven National Laboratory Public Relations Office.

(25) OFFICE OF RADIATION PROGRAMS. Environmental radioactivity surveillance guide, ORP/SID 72–2. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C. 20460 (June 1972).

(26) LENTCH, J. W., M. D. WRENN, T. J. KNEIP, and M. EISENBUD. Manmade radionuclides in the Hudson River estuary. Institute of Environmental Medicine, New York University Medical Center (November 1970).

(27) WILCOX, D. P. and T. K. WENSTRAND. Environmental reports, number 7 through 13. Nuclear Fuel Services, Inc. (January 1970 through December 1972).

(28) HULL, A. P. Brookhaven National Laboratory environmental monitoring report, 1972 (May 1973).

(29) U.S. ATOMIC ENERGY COMMISSION. Draft environmental statement, R. E. Ginna Nuclear Power Plant Unit 1. U.S. Atomic Energy Commission, Directorate of Licensing (April 1973).

(30) U.S. ATOMIC ENERGY COMMISSION. Atomic Energy Clearinghouse, Volume 19, Number 26 (June 25, 1973).

(31) HULL, A. P. Some comparisons of the environmental risks from nuclear and fossil fueled power plants. Health Physics Division, Brookhaven National Laboratories, Nuclear Safety (May/June 1971).

(32) MARTIN, J. A., Jr. Calculations of environmental radiation exposures and population doses due to effluents from a nuclear fuel reprocessing plant. Radiat Data Rep 14:59–76 (February 1973).

Appendix 1[a]

Minimum detectable sensitivity

Air (pCi/m³)

Gross beta	0.003

Fallout (pCi/ft²/day)

Ruthenium-106	25
Zirconium-niobium-95	5
Strontium-89	1
Strontium-90	0.25
Hydrogen-3(pCi/liter)	500

Water and milk (pCi/liter)

Gross Alpha	1
Gross Beta	1
Cesium-137	10
Cesium-134	10
Cobalt-60	15
Ruthenium-106	50
Zinc-65	20
Antimony-125	20
Zirconium-niobium-95	10
Barium-140	15
Iodine-131 (isotopic scan)	10
Iodine-131 (ion exchange)	3
Plutonium-238	0.02
Plutonium-239, -240	0.02
Strontium-89	5
Strontium-90	1
Iodine-129	0.3
Hydrogen-3	500

Maximum permissible concentration

The maximum allowable U.S. AEC yearly average concentration in air for discharges to unrestricted areas in pCi/m³ are:

Gross beta; varies with isotopes present	
Strontium-90	30
Plutonium-238	0.07
Plutonium-239	0.06
Plutonium-240	0.06
Cesium-134	1,000
Cesium-137	2,000
Ruthenium-106	3,000
Zirconium-95	4,000
Barium-140	4,000
Krypton-85	300,000

The maximum allowable U.S. AEC yearly average concentration in water for discharges to unrestricted areas in pCi/liter are:

Gross beta; varies with isotopes present	
Gross alpha; varies with isotopes present	
Iodine-129	60
Iodine-131	300
Strontium-90	300
Strontium-89	3,000
Uranium-234	3,000
Uranium-235	3,000
Uranium-238	4,000
Plutonium-238	5,000
Hydrogen-3	3,000,000
Plutonium-239	5,000
Plutonium-240	5,000
Cesium-134	9,000
Cesium-137	20,000
Cerium-144	10,000
Cobalt-60	30,000
Ruthenium-106	10,000
Antimony-125	100,000
Zinc-65	100,000
Zirconium-95	60,000
Niobium-95	100,000

[a] This table is taken from the 1972 "Annual Report of Environmental Radiation in New York State," New York State Department of Environmental Conservation, Albany, N.Y. 12201.

Calculated Field Intensities Near a High Power UHF Broadcast Installation

Richard A. Tell and John C. Nelson [1]

A UHF transmitter site in the Washington, D.C. area, which is used cooperatively by two UHF television stations, was chosen for calculations of effective radiated power (ERP), field strength, and power density. Using the specifications for the two broadcasting stations, field strengths and power densities were calculated and presented graphically.

The calculated power densities for this broadcasting installation showed that the exposure values fall very sharply as the distance from the tower increases to about 1 mile. At distances beyond 0.5 miles, the maximum exposure values calculated were about 2.7 $\mu W/cm^2$ occurring at 0.5, 3.3, and 4.5 miles. As the height above ground at the receiving point is increased, the exposure value generally increases.

Based on the calculations for the 135 degree radial and the computed population distribution, it appears that approximately 86 000 people reside in an area within which the estimated exposure is 1 $\mu W/cm^2$ or more.

This report concerns itself with ambient radiofrequency (RF) exposure levels in the near vicinity of a high power UHF television (TV) broadcast installation in the Washington, D.C. metropolitan area. Recently, attention has been focused on the discovery of undesirable UHF interference to cardiac pacemakers (*1*) and the long standing interest in the possible long-term, low-level (nonthermal) biological effects of electromagnetic energy in this frequency range (*2*). Though the potential contribution to human RF exposure from broadcast stations has been examined in general (*3*), this report deals specifically with calculation of radiation fields of the UHF broadcast service. More exactly, a first order approximation of radiated field intensity, utilizing transmitter characteristics, antenna vertical radiation patterns, and topographic terrain information, was used to develop power density and field strength curves as a function of distance from a UHF TV installation and varying heights above ground. Additionally, the 1970 census data were used in an automated manner to compute the population residing within areas subject to specific calculated levels of RF exposure.

A UHF transmitter site in the Washington, D.C. area was chosen for the calculations which follow. This particular location (figure 1) is the site of WDCA (channel 20, commercial) and WETA (channel 26, educational), the transmitting antennas of both stations being colocated on the same tower. Table 1 summarizes some of the technical specifications for these two stations. The combined effective radiated power (ERP), including both visual and aural carriers, is approximately 5.6 MW and represents one of the most powerful UHF outlets in this country. A maximum ERP of 5.0 MW for a single station is allowed by the Federal Communications Commission (FCC). As of December 1, 1971, there were 306 UHF television stations on the air in the United States (*4*).

Table 1. Pertinent information for UHF TV complex

UHF TV complex	Channel	
	WDCA–20	WETA–26
Visual carrier frequency (MHz)	507.25	543.25
Aural carrier frequency (MHz)	511.75	547.75
Maximum antenna gain (dB)	13.42	14.39
Antenna manufacturer	RCA	GE
Antenna type	TFU–22g	TY–106C
Visual maximum ERP (kW)	4 000	1 074
Aural maximum ERP (kW)	400	107.4
Elevation of antenna center of radiation (feet)	1 016	1 028

[1] U.S. Environmental Protection Agency, Electromagnetic Radiation Analysis Branch, Office of Radiation Programs, 9100 Brookville Road, Silver Spring, Md. 20910.

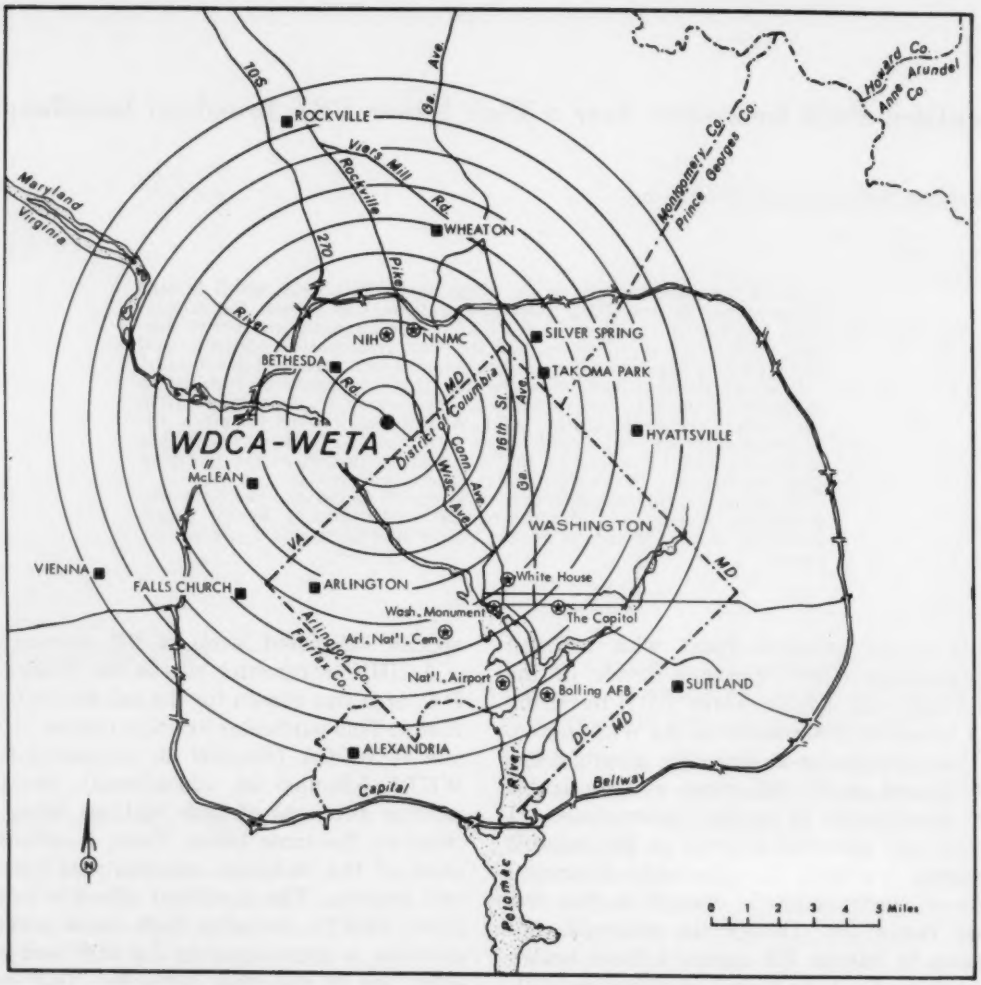

Figure 1. Location of WDCA-WETA transmitting tower

Method

The problem of calculating ground level field intensities from elevated UHF broadcast antennas over a spherical earth can become extremely complex requiring tedious ground reflection coefficient computations (*5–7*). Even when utilizing these more sophisticated analytical techniques, variations in actual terrain and electromagnetic obstacles such as buildings, overhead power lines, automobiles, and foliage often distort the actual field values significantly from those which were calculated. For this reason, a simplified approach was used to estimate, for hazard purposes, the RF field intensities around the WDCA-WETA complex. Figure 2 diagrammatically illustrates this approach. For any exposure point, B, elevated above the earth, there exist two incident waves emitted by the transmitting antenna at a height h_1 above ground; one wave is directly radiated from the tower to the exposure point while another is reflected from the ground at point C. These two waves, depending on their relative

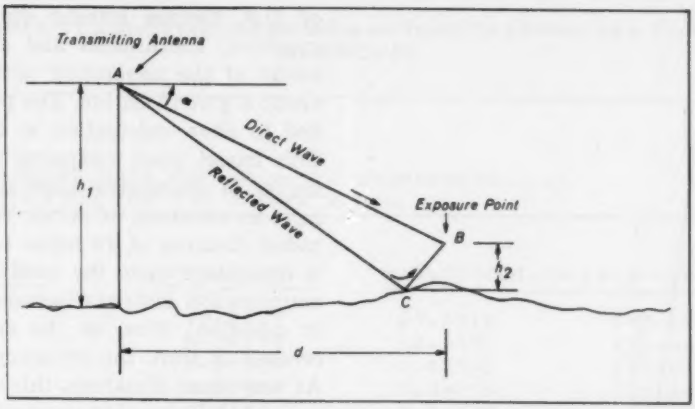

Figure 2. Diagram of approach for estimation of RF field intensities

phase and intensity, will combine (constructively or destructively) at point B to produce a resultant field. In reality, the resultant field tends to oscillate about the value given by the direct wave alone, depending on whether point B is moved vertically above ground or laterally away from the source. In the model used in this report, a worst case assumption has been made, in accordance with FCC recommendations (*8*), that the ground-reflected wave is equally intense as the direct wave and adds vectorially to double the field strength value at point B over what could be accounted for by considering only the direct wave. The assumption of 100 percent ground reflection offers a conservative means of evaluating the maximally potentially hazardous UHF fields.

The RF exposure values calculated were obtained through the free space relation:

$$E_B = \frac{2\,R_\alpha \sqrt{30\,Pt}}{d}$$

where:

E_B = field strength (V/m) at point B,
R_α = relative field factor of TV antenna vertical radiation pattern,
Pt = sum of maximum visual and aural ERP for a given station (W), and
d = distance of point B from antenna tower (m).

The relative field factor, R_α, is determined from manufacturers data for each transmitting antenna as a function of the depression angle α. A plot of R_α vs. depression angle is known as the vertical radiation pattern for a TV broadcasting antenna. Figure 3 is the vertical pattern for the WDCA transmitting antenna. This pattern was obtained from station records maintained by the FCC. Normal practice in plotting relative field data limits the published curves to depression angles of approximately 10 to 11 degrees below the horizontal. Thus, for areas extremely close to the antenna installation where the depression angle may be very steep, data are usually not included in the pattern. However, beyond angles of 10 degrees or so, R_α is usually not changing, and if so, only within a few percent of its value at 10 degrees. For the calculations here, advice from the manufacturers indicated that an R_α value equal to the 10 degree value was applicable for all steeper depression angles.

In practice, actual terrain elevation values (taken from USGS quadrangle topographic maps) were used to compute α and the antenna-to-exposure point distance, each 0.1 mile from the tower. A total of eight equally spaced radials (0 to 10 miles) were used to examine possible differences in ground level values due to topographic features in different directions from the tower site.

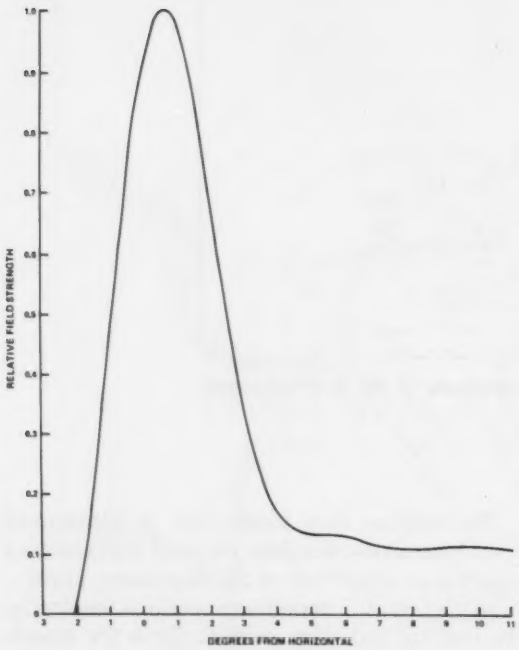

Figure 3. Vertical radiation pattern for the WDCA transmitting antenna

From the calculated field strengths for each station, the resultant power densities were determined by:

$$W = \frac{E^2}{Z_0}$$

where:

W = power density (W/m^2),
E = field strength (V/m), and
Z_0 = intrinsic impedance of free space = 120π ohms.

Exposure values were determined for field strength in units of V/m and dB/(μV/m) and for power density in units of $\mu W/cm^2$ and dB/($\mu W/cm^2$).

An estimate of the population residing in the vicinity of this UHF broadcast installation was made by modifying the computer programs developed by the Institute for Telecommunications Sciences (ITS) in Boulder, Colo. (*9*). The ITS technique allows computer retrieval of U.S. Census Bureau data stored by geographical coordinates and computation via a model of the population within annular rings about a given location. The program was modified to allow calculation at 0.1 mile intervals. This model when compared with manual techniques of estimating population was found to have an accuracy of better than 1 percent at a radial distance of 10 miles (*10*). The accuracy is dependent upon the total number of census enumeration districts included within the area in question; thus, as the radial distance decreases to zero, the accuracy becomes poorer. At very short distances, this error has not been evaluated. Using this approach, however, values for the population in circular areas, increasing by 0.1 mile in radius, were determined for the WDCA-WETA site up to 10 miles.

Results

Table 2 is a sample computer output for WDCA-TV showing the calculated field strength and power density for a distance up to 4 miles. In this listing, the field strength is that value which would be associated with the summation of both visual and aural carriers. The results of these and calculations along other radials are given in figure 4. This graph represents a family of eight curves showing very little effect of differences in terrain profiles. A power density of slightly more than 28 $\mu W/cm^2$ is found directly beneath the antenna at ground level while at 10 miles, the exposure is less than 1 $\mu W/cm^2$. Figure 5 is a dB plot of the 135 degree radial information giving better detail of the field amplitude values. Figure 6 expands the horizontal scale factor, showing the previous information in the 0–3 mile range.

Ground level field strengths (assuming 100 percent ground reflection) are represented in figure 7 for both WDCA and WETA at 135 degrees. At reasonable distances from the tower, when high depression angle detail is no longer important, it can be seen that though WDCA has approximately four times the ERP of WETA, the calculated field strength is only about twice at great.

The effect of increasing the exposure location height above ground can be seen in figure 8.

Table 2. Calculated field strength and power density for a distance up to 4 miles for WDCA-TV

FOLLOWING DATA FOR WDCA-TV, WASHINGTON, D.C.
CALCULATED FOR 135 DEGREE RADIAL

MILES	F.S.(V/M)	P.D.(UW/CM.SQ.)	F.S.(DB/UV/M)
0	10.2137	27.6712	140.184
.1	8.38176	18.635	138.467
.2	6.04035	9.67793	135.621
.3	4.49883	5.36855	133.062
.4	3.5104	3.26867	130.907
.5	2.8701	2.185	129.158
.6	2.42969	1.56588	127.711
.7	2.09779	1.1673	126.435
.8	1.9325	.990597	125.722
.9	1.70991	.775539	124.659
1	1.51407	.608062	123.603
1.1	1.42997	.542392	123.106
1.2	1.43055	.542834	123.11
1.3	1.28734	.439589	122.194
1.4	1.28813	.440126	122.199
1.5	1.23182	.402486	121.811
1.6	1.39712	.51776	122.905
1.7	1.55025	.637474	123.808
1.8	1.67822	.74706	124.497
1.9	1.59009	.670656	124.028
2.	1.76728	.828459	124.946
2.1	2.00245	1.06361	126.031
2.2	2.24876	1.34135	127.039
2.3	2.15132	1.22763	126.654
2.4	2.37666	1.49828	127.519
2.5	2.28163	1.38086	127.165
2.6	2.19414	1.27699	126.825
2.7	2.4828	1.6351	127.899
2.8	2.39419	1.52046	127.583
2.9	2.31161	1.41738	127.278
3.	2.23456	1.32447	126.984
3.1	2.51702	1.68047	128.018
3.2	2.75983	2.02033	128.818
3.3	2.67623	1.8998	128.55
3.4	2.89567	2.22411	129.235
3.5	2.22962	1.31862	126.964
3.6	2.16757	1.24625	126.719
3.7	2.109	1.17981	126.481
3.8	2.0536	1.11864	126.25
3.9	2.52456	1.69056	128.044
4.	2.46132	1.60692	127.823

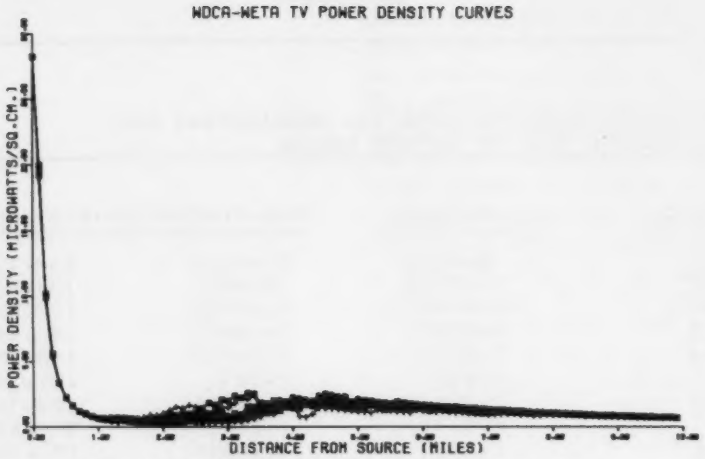

Figure 4. Power density curves along eight radials from WDCA-WETA transmitting antenna

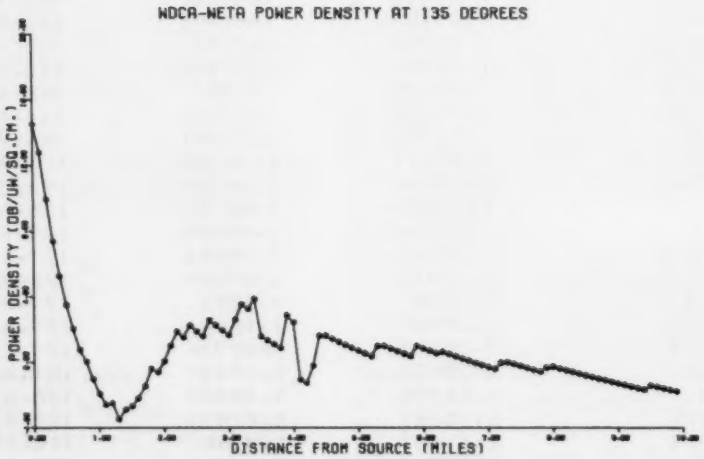

Figure 5. Power density curve along 135 degree radial for WDCA-WETA transmitting antenna (0 to 10 miles)

Separate curves delineate the power density at heights of 0, 100, 200, 300, 400, and 500 feet. The tallest structure in the Washington, D.C. area in which people are allowed is the Washington Monument at 555 feet. Most buildings in the District of Columbia are substantially lower than the Monument. Two buildings very near the WDCA-WETA site, both high-rise apartment buildings, are 143 feet above ground. The buildings are within 0.5 miles of the tower.

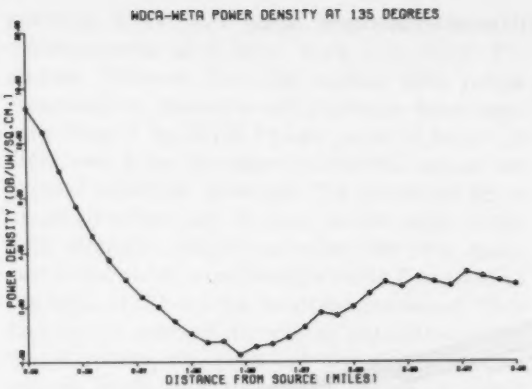

Figure 6. Power density curve along 135 degree radial for WDCA-WETA transmitting antenna (0–3 miles)

Computer generated values for population about the transmitting site were determined on the ITS computer and then the data were reformatted and machine plotted by EPA. Figure 9 shows the results for a distance up to 10 miles from the site. From this curve, it is possible to estimate the number of persons living within various distances for which estimates of RF exposure were made. For the area defined by a 10-mile radius, the population estimate is 1.60 million. Based on 1960 census data, this number was 1.38 million. Within extremely close distance to the site coordinates (0.3 miles), the computed population is 0, due to the fact that the computer program searches for a population centroid with coordinates lying within the given radius. Out to a radius of 0.3 miles from the tower, no population centroids were found. At a radius of 1 mile, however, 19 census enumeration districts (CEDs) had been located. Table 3 is a listing of the number of CEDs within 10 miles at intervals of 1 mile.

Table 3. Census enumeration district distribution

Radius in miles	Number of census enumeration districts
1	19
2	72
3	140
4	221
5	430
6	673
7	894
8	1 132
9	1 313
10	1 497

Discussion and conclusions

The calculated power densities for the WDCA-WETA broadcasting installation show that with the conservative assumptions made in this process, the exposure values fall very sharply (by about 16 dB) as the distance from the site increases to approximately 1 mile. This

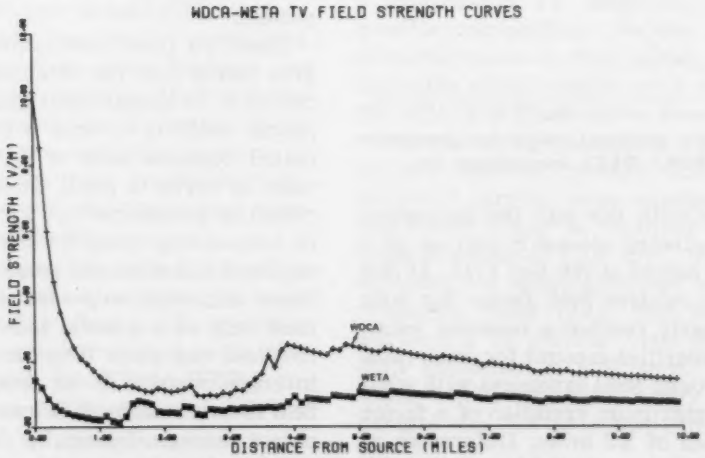

Figure 7. Ground level field strength curves for WDCA-WETA along the 135 degree radial

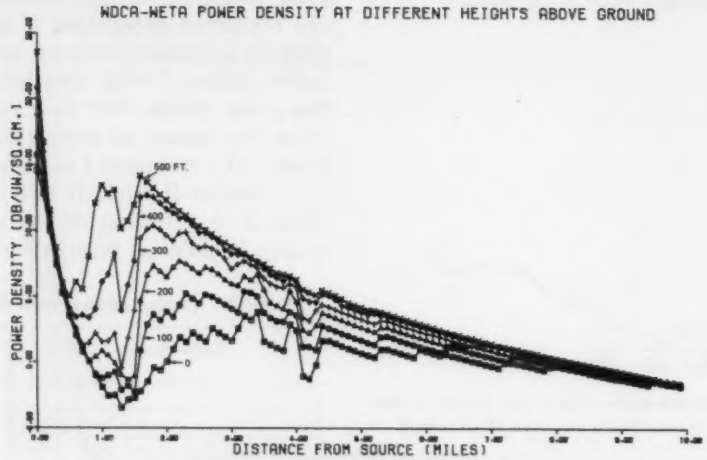

Figure 8. Power density curves for WDCA-WETA transmitting antenna at various heights above ground

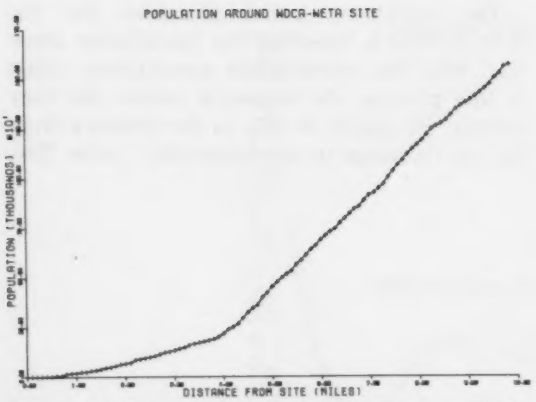

Figure 9. Computer generated values for population around the WDCA-WETA transmitting site

is in accordance with the way the depression angle α varies, α being almost 8 degrees at 1 mile for a tower height of 750 feet (*11*). At this small angle, the relative field factor for both antennas has nearly reached a constant value.

Terrain irregularities account for observable differences in ground level exposures with what appears to be a maximum variation of a factor of 5 at a distance of 3.3 miles. Differences at other distances between individual radial directions are, in general, substantially less. The region of most directional variation in exposure occurs between approximately 2 and 5 miles. At distances beyond 0.5 miles, the maximum exposure values calculated were about 2.7 $\mu W/cm^2$ occurring at 0.5, 3.3, and 4.5 miles.

As the height above ground at the receiving point is increased, the exposure value remains fairly constant. Except in the region very near the tower base (i.e., less than 0.5 mile), the distance at which the peak power density occurs increases slightly with decreasing height above ground.

Based on these calculations for the 135 degree radial and the computed population distribution, it appears that approximately 86 000 people reside in an area within which the estimated exposure value is 1 $\mu W/cm^2$ or more. It must be borne in mind, though, that these calculations assume perfect ground reflection and no intervening obstacles and thus represent an idealized situation not present in reality. Thus these computed exposure estimates must be used only as a general indication of potential idealized exposure. How far the estimates are in error remains to be determined by actual field measurements. It is known that free space values diverge drastically from actual values in typical environments and as the distance between transmitter and receiver increases. For

example, it has been found from field strength measurements of a New York City UHF TV station (channel 31) that actual field values measured on unobstructed roof-tops were typically from 7 to 13 dB (mean value of about 10 dB) down from free space calculated values (no ground reflection assumed) for distances up to about 13 miles (*12*). In fact, in this same study, field strengths which exceeded the free space calculated value were found at only 3 percent of the total 3179 roof-top locations measured. This finding, if applied to values calculated here, would reduce the potential power density exposure levels indicated by a factor of about 1/36. Such a reduction probably places the farther-away values in a more realistic range. Calculated values very near to the source (1 mile) are probably more nearly correct due to lack of intervening terrain clutter.

The attenuating effect of buildings also tends to reduce actual field values substantially. In the above mentioned study, indoor field strength measurements showed field strengths relative to free space in the range of –39 to –47 dB (mean value of about –43 dB) for the UHF channel or an additional perturbation of about 33 dB due to building effects. Other studies of insertion loss effects of buildings show similarly high values of attenuation (*13*).

The essence of these experimental findings indicates that calculated values of field intensity cannot be used to explicitly define whether an RF hazard exists or not; actual field measurements are necessary to verify predictions. Nevertheless, first order approximations can serve to identify areas requiring further investigation. Also, the possibility of complex standing wave configurations resulting in extra intense fields support the more conservative calculational approach until supplementary measurement data are available.

Regardless of the possible error in the values computed here, it is safe to say that, in terms of a direct thermalizing effect of RF (generally associated with exposures greater than 10 mW/cm^2) no areas around the WDCA-WETA site appear to present an RF exposure hazard. The currently accepted RF levels considered safe for continuous occupational exposure are defined in the ANSI (*14*), USAF-Army (*15*), ACGIH (*16*), and OSHA (*17*) standards as 10 mW/cm^2 for the UHF frequency region. Whether these guides should apply to the general populace as a whole has not been decided. The possibility of interference to critical devices, such as cardiac pacers and electroexplosive devices, is a more difficult situation to assess. No standards, per se, exist which define hazardous vs. nonhazardous levels of RF for these devices from an interference standpoint. It has been found that cardiac pacers are apparently more susceptible to pulsed RF fields (similar to radar transmission) than to continuous wave (CW) type fields (similar to TV transmission). However, extensive testing of a variety of pacers indicates that some combinations of CW type signals which produce a rapidly changing electric field gradient can be viewed as "pseudo-pulsed" fields giving rise to pacer interference (*18*). In one case, a pacer failure in the vicinity of a high power UHF TV station has been attributed to the varying amplitude of the station's signal (*1*). It was felt that bursts of detected video modulation or synchronization pulses were not of sufficient length to cause automatic reversion to a fixed pacer rate which is a feature of some pacemakers when exposed to high frequency interference. Fields strengths in the mentioned case were between 0.5 and 1.0 V/m. Additionally, recent unpublished data has revealed disruption of pacemaker operation near the tower of a multistation TV broadcast outlet.[2] Despite possible variabilities in the computed field strength values in this report, fields of these strengths should readily exist within 1 mile of the WDCA-WETA site.

An interesting possibility is brought to light by this exercise; namely that, in the UHF broadcast service, large numbers of people in this country may be routinely exposed to RF fields in excess of 1 μW/cm^2. This is the Soviet standard for nonoccupational exposure in this frequency band (*19*). For Soviet radiation workers, a 10 μW/cm^2 level is permitted for daily exposures of 6–8 hours. Field measurements will be required to verify that routine exposures like this do in fact exist. However, the

[2] Personal communication with J. C. Mitchell, February 16, 1974.

implication is fairly strong that at least some selected population groups, near the higher power UHF stations are exposed to levels exceeding 1 $\mu W/cm^2$ and thus raises the question of the applicability of the Soviet standard as an environmental exposure limit in the United States.

In conclusion, first order approximations to ground level field intensities from a UHF TV broadcast complex have been made for hazard analysis purposes. Though at modest distances from the source, large differences between calculated values and actual values can exist (calculated values being higher), computed values very near the source should be useful for establishing the existence of high-level, thermalizing hazards. In the case examined, under no circumstances can field intensities greater than 28 $\mu W/cm^2$ be envisioned at ground level, this being directly beneath the tower. Since the case considered here represents a combined effective radiated power greater than the maximum possible authorized power for a single UHF TV broadcast station, it is inconceivable that for similar tower heights any single UHF TV station in the U.S. could produce fields greater than those calculated.

REFERENCES

(*1*) D'CNBA, G. F., T. NICOUD, A. H. PEMBERTON, F. F. ROSENBAUM, and J. T. BOTTICELLI. Syncopal attacks arising from erratic demand pacemaker function in the vicinity of a television transmitter. Amer J Cardiol 31:789–791 (June 1973).

(*2*) OFFICE OF TELECOMMUNICATIONS POLICY. Report on program for control of electromagnetic pollution of the environment: the assessment of biological hazards of nonionizing electromagnetic radiation. Executive Office of the President (March 1973).

(*3*) TELL, R. A. Broadcast radiation: how safe is safe? IEEE Spectrum 9:43–51 (August 1972).

(*4*) BROADCASTING PUBLICATIONS, INC. Broadcasting 1972 Yearbook, Washington, D.C. (1971).

(*5*) BURROWS, C. R. Radio propagation over plane earth—field strength curves. Bell System Tech J 16:45–75 (January 1937).

(*6*) BULLINGTON, K. Radio propagation at frequencies above 30 megacycles. Proceedings IRE (October 1947), pp. 1122–1136.

(*7*) NORTON, K. A. The propagation of radio waves over the surface of the earth and the upper atmosphere—Part II. Proceedings. IRE, Vol 25 (September 1937) pp. 1203–1236.

(*8*) DAMELIN, J. VHF-UHF radiation hazards and safety guidelines, Report No. 7104. Federal Communications Commission, Office of the Chief Engineer, Research Division, Washington, D.C. 20554 (July 19, 1971).

(*9*) EWING, D. R. and J. A. PAYNE. Computer access to geographic distribution of the population. U.S. Department of Commerce, Office of Telecommunications Technical Memorandum, Washington, D.C. 20235 (July 1973) pp. 73–146.

(*10*) NORTON, R. A., D. R. EWING, P. G. RATCLIFF, and R. S. KIRBY. The distribution of the population in the continental United States, Canada and Mexico within various distances from 1361 television market centers. ESSA Technical Memorandum ERLTM–ITS 244. U.S. Department of Commerce, Washington, D.C. 20235 (August 1970).

(*11*) TELL, R. A. Reference data for radiofrequency emission hazard analysis, OPR/SID 72–3. U.S. Environmental Protection Agency, Washington, D.C. 20460 (June 1972).

(*12*) WALDO, G. V. Report on the analysis of measurements and observations—New York City UHF-TV project, No. R–6303. Federal Communications Commission, Office of the Chief Engineer, Research Division (March 27, 1963).

(*13*) RICE, L. P. Radio transmission into buildings at 35 and 150 Mc. Bell System Tech J 38:197–210 (January 1959).

(*14*) AMERICAN NATIONAL STANDARDS INSTITUTE. Safety level of electromagnetic radiation with respect to personnel, Report ANSI–C95.1 (1966).

(*15*) U.S. DEPARTMENTS OF THE ARMY AND THE AIR FORCE. Control of hazards to health from microwave radiation, Report TB MED 270–AFM 161–7 (December 1965).

(*16*) AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS PUBLICATION. Threshold limit values of physical agents with intended changes adapted by ACGIH for 1971. Cincinnati, Ohio (1971).

(*17*) DEPARTMENT OF LABOR. Occupational safety and health administration, Section 1910.97 Federal Register: 36:105 (May 29, 1971), nonionizing radiation effective August 27, 1971.

(*18*) MITCHELL, J. C., W. D. HURT, W. H. WALTERS, and J. K. MILLER. Empirical studies of cardiac pacemaker interference. Aerospace Medicine (February 1974), pp. 189–194.

(*19*) ACADEMY of MEDICAL SCIENCES, USSR. Safety standards and regulations for handling sources of high, ultrahigh and superhigh frequency electromagnetic fields, No. 848–70 AMN, Russian (March 30, 1970), pp. 3–34.

Analysis of Radiation Exposures on or Near Uranium Mill Tailings Piles

Keith J. Schiager[1]

Potential radiation exposures from abandoned uranium mill tailings piles may be predicted in a general manner using minimal input data. If the average radium concentration in the tailings C_{Ra} is known, the external gamma exposure rate over the tailings can be estimated from: X (μR/h) $\cong$ 2.5 C_{Ra} (pCi/g). The radon emanation rate can also be estimated as: ϕ (pCi Rn/m^2–s) $\cong$ 1.6 C_{Ra} (pCi/g). The reductions of exposure rates that can be achieved by covering the tailings with earth or concrete also are discussed. Radon progeny inhalation exposures depend upon the dispersion rate of radon in the atmosphere and the time available for progeny ingrowth. Meteorological data for the site are required for making reliable predictions of inhalation exposures. It is shown, however, that contributions to the average annual outdoor radon progeny concentrations exceeding 0.003 WL are very unlikely on or near any tailings pile. The methods used to analyze potential radiation exposures are illustrated by a case study on one abandoned tailings pile.

Uranium mill tailings piles are a source of potential radiation exposure to persons in the immediate vicinity. During the period of active use, exposures are primarily confined to mill personnel and are classified as occupational. For the purpose of preparing environmental reports, however, mill operators need to predict exposure rates that would occur both during use and also after stabilization. The analytical methods presented herein may be helpful in preparing such environmental reports.

Abandoned tailings piles present some special problems in addition to those encountered with active piles. If left unstabilized, an abandoned pile serves as a continuing source of environmental contamination as a result of wind and water erosion. The cost of stabilization, however, may be a significant economic burden if required of an owner who cannot realize an associated land-use benefit. Furthermore, even a stabilized pile represents a long-term net cost to the community if it cannot be used in some productive manner; the actual cost depends, of course, on the location of the pile and its potential for development.

The construction of enclosed buildings on, or immediately adjacent to, tailings piles is not thoroughly considered in this analysis; such use is not usually an acceptable option. However, data on the effectiveness of concrete slabs for reducing exposures are included since some potential uses of tailings may involve concrete surfacing. These data also can be applied in the analysis of exposures in structures already built over tailings.

Basic principles

The analytical methods presented in this discussion, and the kinds and sources of data required to support the analysis, were determined by the following basic principles.

Short-term stabilization versus long-term risk

At the present time, there is no proven method that is economically feasible for permanently eliminating the possibility of radiation exposures from radium-bearing tailings left on the earth's surface. The half-life of radium-226 is more than 1600 years, and typical uranium mill tailings contain radium concentrations approximately 100 times greater than ordinary Colorado soil (*1,2*). To reduce the radiation exposure potential to a level comparable to the normal background would require a decay time

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of more than 10 000 years. If the thorium-230 precursor of radium-226, with a half-life of 80 000 years, is present in significant quantities, the time element of the argument would be extended accordingly. No human institution, government or private, can effectively guarantee control over any parcel of land for thousands of years.

Any form of control or stabilization, whether by productive development or by nonproductive access restrictions, can be considered valid for only one or two generations. Consequently, any decision on a potential utilization of a tailings site should be based upon the careful appraisal of both the predictable radiation exposures and the expected benefits of the alternative choices over the time period of the anticipated utilization.

Radiation exposure sources

Radium and its decay products can produce radiation exposures through three basic routes; each potential exposure route must be considered independently.

1. Ingestion. Radium may be leached from tailings and enter surface waters or subsurface aquifers. The radium may subsequently be ingested directly with the water or transferred to humans through foods. The obvious preventive measure is to prevent leaching of the tailings. Whether to be used productively or not, a tailings pile should be contoured and covered in a manner that will minimize both leaching and erosion. In general, the risk of radium ingestion will be reduced in direct proportion to the thickness and durability of the cover material used for stabilization. The risk of contamination of water with radium is primarily dependent upon local variables, e.g. topography, soil characteristics, proximity of surface waters and subsurface aquifers, climate, etc. The risk of ingestion cannot be generalized as readily as can the other exposure risks and, consequently, is not considered further here.

2. Inhalation. Radium decays to radon, a noble gas that diffuses readily in air, as well as through many apparently solid materials. The radon that is produced in the uranium decay series is radon-222 which has a half-life of 3.8 days, or a mean lifetime of 5.5 days. During this mean lifetime, a radon atom may be transported hundreds of miles through the atmosphere. However, it would diffuse only a few feet through earth or tailings, and only a few inches through good concrete, during its lifetime.

The inhalation exposure of greatest importance is produced by the short-lived decay products of radon, rather than by the gas itself. Following its decay as radon, an atom progresses through four additional decays in a mean time of 74 minutes, emitting 2 alpha and 2 beta particles in the process. Most of the gamma rays arising from the radium decay series also originate from these short-lived progeny. Inhaled radon progeny atoms can deposit as solid particles in the respiratory tract. Completion of their decay sequence at or near the site of deposition produces a highly localized radiation dose to the respiratory epithelium, particularly due to the short-range alpha particles.

Concentrations of radon progeny in air are commonly expressed in units of working levels (WL)[2]. One WL is equivalent to the radon progeny that would be present in equilibrium with a radon concentration of 100 pCi/liter. Equilibrium in air between radon and its progeny is rarely approached, however, except outdoors at some distance above the ground. Even outdoors, therefore, it is necessary to determine radon progeny concentrations, as opposed to radon only.

3. External. Most of the radon produced by decay of radium is trapped in solid particles. In typical tailings, the "emanating power" (i.e. the fraction of the radon that is free to diffuse) is approximately 20 percent (*1*). The remaining radon (80 percent), plus all of the associated decay products, provide a source of gamma rays from within the tailings.

In contrast with ingestion or inhalation exposures, external gamma rays expose the entire body, including the gonads, blood-forming organs, and other sensitive tissues. However,

[2] One WL is defined as any combination of radon progeny in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of alpha energy during decay to lead-210.

this source of exposure can be reduced and controlled much more easily than can the emanation of radon. The feasibility of reducing gamma exposure rates essentially to normal background levels is presented in a following section.

Annual averages

All of the radiation protection guides for the general public are based upon averages over a period of 1 year or longer. For each type of variable exposure, therefore, it is necessary to determine long-term averages rather than relying upon single measurements or peak values. The evaluation of long-term average exposures must include consideration of reasonable annual occupancy factors as well as the variability of the exposure rates. Any radiation exposure situation that involves less than 24 hours/day and 365 days/year of exposure time must be evaluated on the basis of the maximum potential exposure to any individual and the predicted average exposure to a population group.

Simplifying assumptions and approximations

In keeping with the proposed applications of the data and methods which follow, namely to permit reasonably accurate exposure estimates to be made for alternative uses of tailings locations, certain approximations are used to simplify the calculations. Sufficient background information and data are included, however, to support the simplifications. In view of the numerous environmental variables that affect the potential radiation exposures, the use of simplifying assumptions is believed to be justified. The accuracy of the exposure predictions depends much more heavily on the validity of the data introduced into the calculations than it does on the analytical approximations.

Both customary and metric units are used throughout the presentation depending on common usage for the quantity involved. Although all quantities were converted to metric units for purposes of calculation, many customary units were retained in the figures and text for the convenience of readers.

Table 1. Gamma-ray emission and exposure data for radium (*1*, *4*)

Number of photons per radium decay	2.184
Total photon energy per radium decay	1.80 MeV
Mean photon energy	.824 MeV
Flux at 1 meter from a 1 curie point source:	
Photon flux	6.4×10^5 photons/cm^2–s
Energy flux	5.3×10^5 MeV/cm^2–s
Fluence-to-exposure conversions:	
Photon fluence	2 300 photons/cm^2–μR
Energy fluence	1 900 MeV/cm^2–μR
Gamma-ray exposure constant (for a source sealed in 0.5 mm platinum)	.84 R/h at 1 m from 1 Ci

External gamma-ray exposures

Most tailings sites are sufficiently large that they may be treated as slabs of infinite area for purposes of calculating gamma-ray exposures directly over the surface. The unscattered flux of gamma rays reaching a point near the surface of an infinite slab source can be expressed as (*3*):

$$\Phi = S/2\mu\,[1 - E_2(\mu x)]$$

where: Φ = primary gamma-ray flux (photons/cm^2-s)
S = gamma-ray emission rate (photons/cm^3-s)
μ = linear attenuation coefficient in the slab material (cm^{-1})
x = slab thickness (cm)
$E_2(\mu x)$ = second order exponential integral

$$= \mu x \int_{\mu x}^{\infty} e^{-u} u^{-2}\, du$$

The radium decay series produces gamma rays over a broad range of energies and relative emission rates. The linear attenuation coefficient, μ, is also energy dependent. Thus, a precise calculation of the unscattered photon flux above the slab would require a summation of the contributions of the gamma rays of each energy. It is possible, however, to obtain reasonably good results using values that have been appropriately averaged for the entire energy spectrum. Some appropriate numerical values are shown in table 1. A graph of the function $[1 - E_2(\mu x)]$ versus μx is shown in figure 1.

Data pertaining to both source terms and shielding functions are listed in table 2. The activity concentration shown for tailings (C_{Ra}

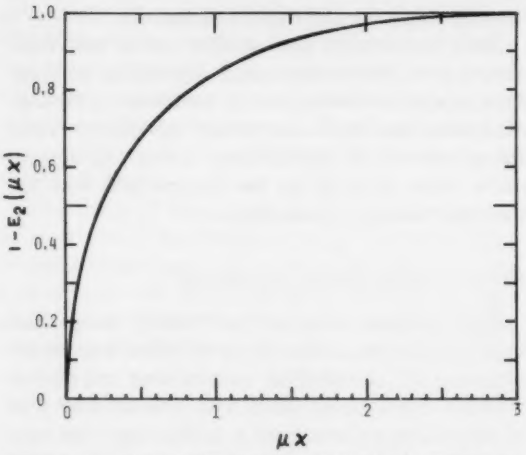

Figure 1. Plot of the function $1-E_2(\mu x)$ versus μx

Table 2. Exposure rate variables for environmental radium and radon (values are typical or reasonable averages) (*1*)

Variable	Tailings (dry packed)	Earth (moist packed)	Concrete (ordinary)
Radium concentration, C_{Ra} (pCi/g)	250	2	2
Density, ρ(g/cm³)	1.6	1.6	2.35
Attenuation coefficient, μ(cm⁻¹)	.11	.11	.16
Tenth value layer ($I_X = 0.1\ I_0$)	—	13 inches	9 inches
Porosity (fraction void)	.36	.25	.06
Diffusion coefficient, D(cm²/s)	5×10^{-2}	5×10^{-2}	2×10^{-6}
Relaxation length, ($C_X = C_0/e$)	1.5 m	1.5 m	5 cm

= 250 pCi/g) is considered typical for the sand portion, although actual concentrations may range from 130 to 300 pCi/g. The radium concentrations shown for earth and concrete are approximations only; actual values generally are in the range of 0 to 10 pCi/g.

Based upon the data contained in tables 1 and 2, one can calculate the emission rate of the unscattered photons:

$$S = (C_{Ra}\ \text{pCi/g})\ (0.037\ \text{dis/s-pCi})\ (1.6\ \text{g/cm}^3)\ (2.184\ \text{photons/dis})$$
$$= 0.13\ C_{Ra}\ \text{photons/cm}^3\text{-s}$$

where C_{RA} = concentration of radium in the tailings (pCi/g)

For values of μx greater than 3, the function $[1 - E_2(\mu x)]$ is essentially equal to 1 and the unscattered flux will be the same as that from an infinitely thick slab:

$$\Phi = S/2\mu = (0.13\ C_{Ra}\ \text{photons/cm}^3\text{-s})/2(0.11\ \text{cm}^{-1})$$
$$= 0.59\ C_{Ra}\ \text{photons/cm}^2\text{-s}$$

The contribution of the unscattered flux to the exposure rate is then calculated to be:

$$X = (0.59\ C_{Ra}\ \text{photons/cm}^2\text{-s})\ (3600\ \text{s/h})/(2300\ \text{photons/cm}^2\text{-}\mu\text{R})$$
$$= 0.92\ C_{Ra}\ \mu\text{R/h}$$

The total exposure rate over the slab, however, is only partially due to unscattered gamma rays. Scattered gamma rays contribute more to the exposure rate over the slab than the primary photons do. It is necessary, therefore, to incorporate a "buildup factor" into the calculations to account for the exposure contribution from the scattered radiation.

Buildup factors can be, and have been, calculated on a theoretical basis, but this approach requires sophisticated data and computerized analyses. The more common approach is to determine the buildup factor empirically by finding the function that best fits the experimental data. Most buildup factors reported in the literature (*3,4*) are applicable to slabs of shielding materials, rather than to slab sources. The following buildup factor is proposed for use in calculations involving tailings piles since it fits the available experimental data quite well:

$$B = e^{\mu x/1+\mu x}$$

Since the value of μ varies from approximately 0.11 cm⁻¹ in dry tailings to 0.16 cm⁻¹ in concrete, the value of B increases very slowly for x greater than 60 cm, or 24 inches. The values of $[1 - E_2(\mu x)]$ and of B need be determined only if one is concerned with shallow slabs of tailings. For such situations, the graph shown in figure 2 can be used to determine the fraction of the maximum exposure rate that would be produced over the slab. Because of the steep slope of the curve for slab thicknesses of only a few inches, the determination of the slab thickness is crucial for predicting exposure rates over thin layers of tailings.

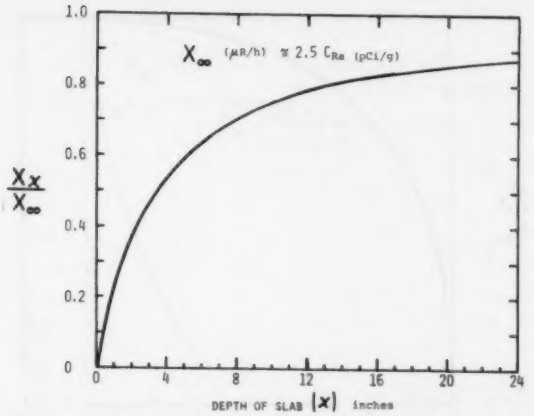

Figure 2. Fractional contribution to gamma exposure rate at surface depth of infinite slab of earth (or tailings) containing radium

For any situation involving tailings depths of more than 1 or 2 feet, the value of μx becomes very large, and the external exposure rate over the tailings can be calculated as follows:

$$X\ (\mu R/h) = 0.92\ e\ C_{Ra}\ (pCi/g)$$
$$= 2.5\ C_{Ra}\ (pCi/g)$$

The relationship calculated above is in excellent agreement with a simplified formula presented by Hultqvist (*5*) for determining the dose rate above soils containing radium:

$$D\ (mrads/yr)\ in\ air =$$
$$18.4 \times 10^{12}\ S\ (g\ Ra/g\ soil)$$

This formula, when converted to the units used in this paper, becomes:

$$X\ (\mu R/h) =$$
$$\frac{18.4\ (g\text{-}mrad/pCi\text{-}yr)\ C_{Ra}\ (pCi/g)\ 10^3\ (\mu R/mR)}{8766\ (h/yr)\ (0.877\ rad/R)}$$
$$= 2.4\ C_{Ra}\ (pCi/g)$$

It should be pointed out here that accurate measurements of external gamma-ray exposure rates in the environment are not generally obtained with portable survey instruments. Most instruments are calibrated against point sources exhibiting only the primary photon energy spectrum. Because of the energy dependence of most survey instruments, they tend to over-

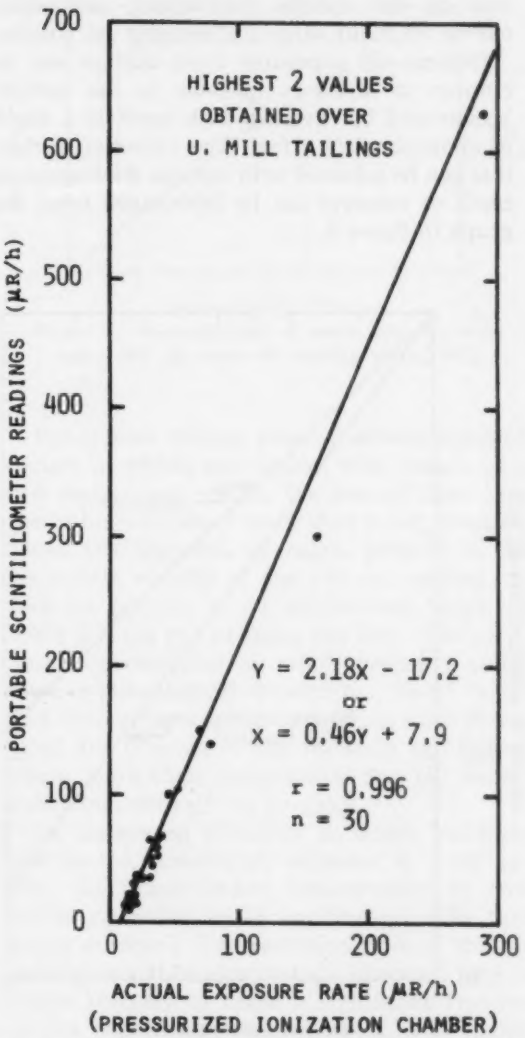

Figure 3. Scintillometer readings versus gamma exposure rate measured with a pressurized ionization chamber at identical locations

respond to scattered radiation, which comprises 60 to 70 percent of the total in the environment. Figure 3 shows a calibration curve for a scintillation crystal (NaI) survey meter that was calibrated to read the correct exposure rate when exposed to a point source of radium. In general, readings obtained over tailings locations were more than double the true exposure rate, as determined with a pressurized ioniza-

tion chamber. Although this calibration applies only to one specific instrument, calibration curves for many other instruments are similar.

Gamma-ray exposures from tailings can be reduced to levels comparable to the natural background by covering with earth to a depth of approximately 2 feet. The reduction factors that can be achieved with various thicknesses of earth or concrete can be determined from the graph in figure 4.

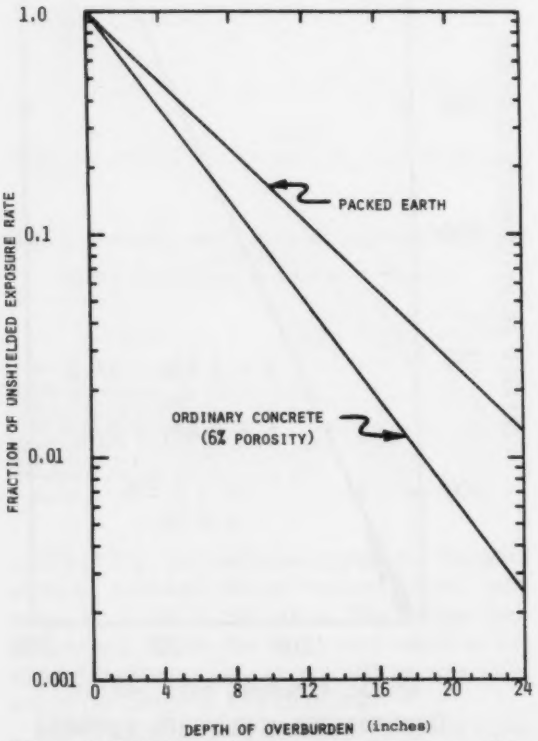

Figure 4. Reduction of gamma exposure rate resulting from earth or concrete shielding (2)

Radon emanation

The rate of radon emanation from a thick slab of uranium mill tailings is primarily dependent on the radium concentration and the fraction of the radon that escapes from the solid particles and is free to diffuse. The radon flux expected at the surface of a slab of dry tailings is shown in figure 5 as a function of slab thickness. The shape of the curve is similar to that which describes the gamma-ray flux; the most notable difference is the scale for the depth of tailings. A slab of 6 to 10 feet in depth is required to produce the maximum radon flux. The relationship between the maximum radon flux and the radium concentration is:

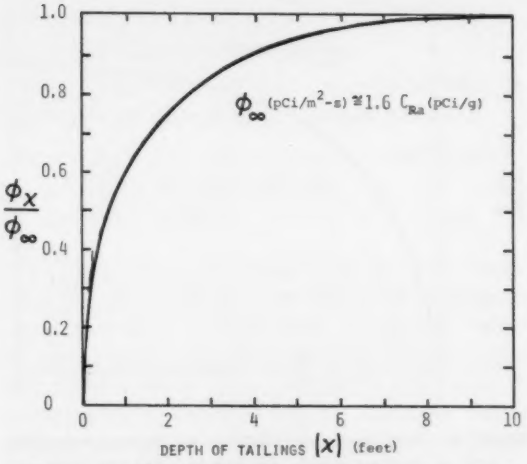

Figure 5. Fractional radon emanation rate versus depth of bare tailings (1)

$$\frac{\Phi_\infty \ (\text{pCi Rn/m}^2\text{-s})}{C_{Ra} \ (\text{pCi Ra/g})} = 1.6$$

$$\text{or } \Phi_\infty \ (\text{pCi/m}^2\text{-s}) = 1.6 \ C_{Ra} \ (\text{pCi/g})$$

For tailings depths of only a few feet, the flux can be predicted as a fraction (Φ_x/Φ_∞) of the flux for a slab of infinite thickness, as shown in figure 5.

Radon emanation cannot be stopped as readily with earth as can gamma rays. As shown in table 2, the "relaxation length" (the distance required to reduce the radon concentration by a factor of e) is approximately 1.5 meters of earth, or approximately 10 times greater than the thickness required to reduce the gamma-ray exposure rate by the same factor. Consequently, the thickness of earth cover required to reduce the radon flux to a level equivalent to the normal background would be approximately 20 feet. On the other hand, the diffusion coefficient for radon in concrete is approximately three orders of magnitude smaller than it is in earth. The

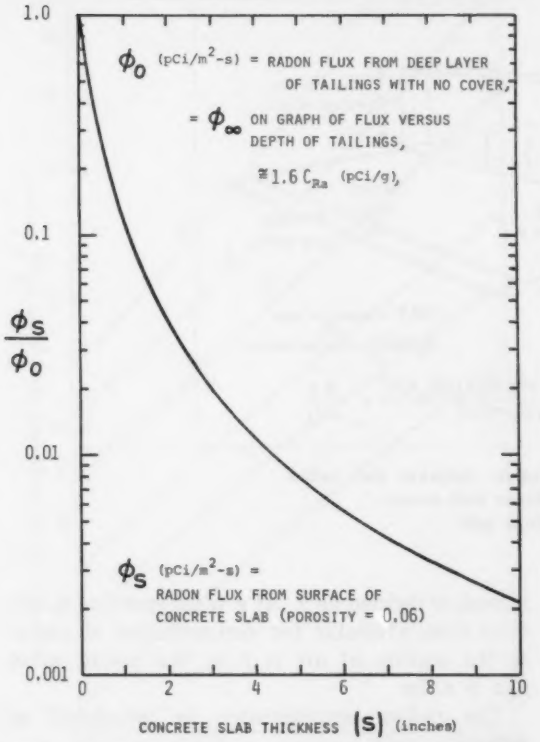

Figure 6. Fractional radon emanation rate through concrete slab placed over a thick layer of tailings versus slab thickness (*1*)

relaxation length is correspondingly shorter (5 cm or 2 inches), indicating the potential of using concrete slabs to reduce radon diffusion, as shown in figure 6.

Radon progeny ingrowth

The concentration of radon in the atmosphere depends upon the rate of dispersion as well as upon the rate of emanation into the atmosphere. The actual inhalation exposure, however, is determined by the concentration of radon progeny which is also dependent upon the mean "age" of the radon. Evans (*6*) has presented a detailed but concise analysis of the behavior of radon progeny. The radon progeny concentration per unit concentration of radon, for ingrowth times up to 12 minutes, starting with radon contamination only, is shown in figure 7.

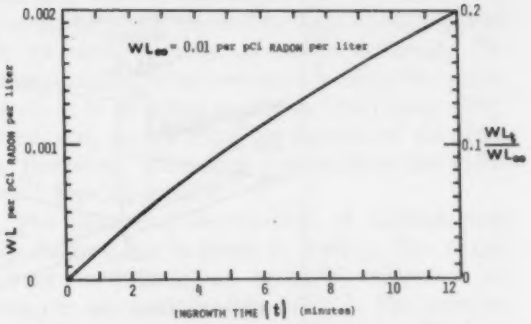

Figure 7. Ingrowth rate of radon progeny from radon-222 (in units of working levels, WL)

For typical tailings piles of several hundred meters in width, and typical wind speeds of a few meters per second, the transit time over the tailings is rarely more than a few minutes. Thus, the ingrowth of radon progeny in the immediate vicinity of the pile can seldom exceed 10 percent of its equilibrium value, or 0.001 WL per pCi of radon per liter. The maximum concentration of radon progeny, under most meteorological conditions, would occur just beyond the edge of the pile; further downwind, the dilution of the radon in the atmosphere more than compensates for the subsequent ingrowth of the progeny.

In the special situation in which buildings are located immediately adjacent to a tailings pile, the indoor radon concentration in such buildings would be in equilibrium with that found outdoors. The residence time of the air indoors would be long enough, however, for the radon progeny to reach a significant fraction of the equilibrium concentration. It is highly likely that the radon progeny concentration in a building adjacent to, but not on, a tailings pile would be higher than the maximum outdoor concentration. Such situations obviously require more detailed evaluations.

Atmospheric dispersion

The method used to calculate the concentration and mean age of radon in the atmosphere is shown in figure 8. The method is based on one important assumption: that the lateral extent of the area source (tailings), upwind

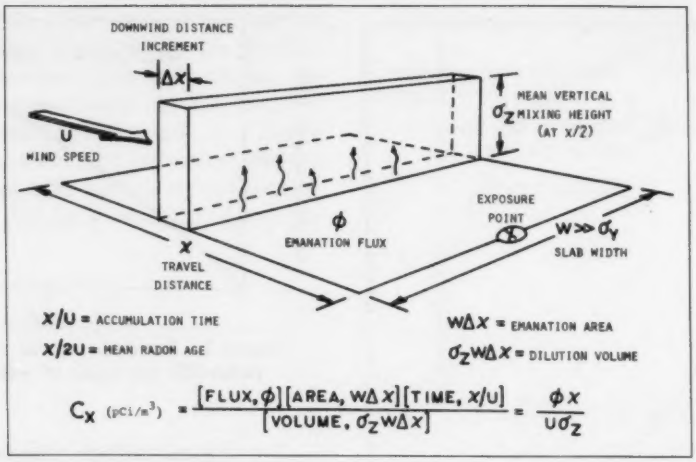

Figure 8. Atmospheric dilution diagram for radon emanating from a large slab source, e.g., a tailings pile

from the point where the concentration is to be determined, is large compared to the horizontal dispersion coefficient for the assumed meteorological condition. This assumption will always be satisfied if the width of the upwinding tailings area, w, is of the same order of magnitude as the travel distance in the direction of the wind, x.

Horizontal and vertical dispersion coefficients, σ_y and σ_z, represent the mean mixing distances, for various meteorological conditions, as functions of the downwind travel distance (7). For the stated assumption, i.e. $w >> \sigma_y$, the actual value of σ_y is not required for the analysis to be made here. However, the value of σ_z is crucial; values of σ_z for x in the range of 100 to 1000 meters are plotted in figure 9.

Consider a thin section of air extending across the tailings slab in a direction normal to the wind. The area of this section of air at the slab surface is $w\Delta x$, where Δx is a small increment of distance in the direction of the wind, and w is the width of the slab. The height of this section of air is assumed to be the mean vertical mixing height, σ_z, at the mean travel distance, x/2.

The total distance in the direction of the wind, from the upwind edge of the source area to the point where the concentration is to be determined, is defined as x. At a wind speed of u, the total time available for accumulation of radon in the section of air is x/u; the mean radon age is x/2u.

The radon concentration is calculated as follows:

$$C_{Ra}\ (pCi/m^3) = \frac{[\phi\ (pCi/m^2\text{-}s)]\ [w\Delta x\ (m^2)]\ [x/u\ (s)]}{[w\Delta x \sigma_z\ (m^3)]}$$

$$= \phi x/u\sigma_z\ (pCi/m^3)$$

$$= 10^{-3}\ \phi x/u\sigma_z\ (pCi/liter)$$

The preceding calculation applies strictly to instantaneous conditions and to locations on or immediately adjacent to a tailings pile. The concentration at a distance, d, further downwind from the tailings pile, may be estimated from:

$$C_{Rn}\ (\text{at } x+d) = C_{Rn}\ (\text{at } x)\ \frac{\sigma_y\sigma_z\ (\text{at } x)}{\sigma_y\sigma_z\ (\text{at } x+d)}$$

In this case, the mean travel time, or the mean age of the radon, would be $(d+x/2)u$. Beyond the range for which this calculation is valid, the radon concentration will be too low to be of much interest.

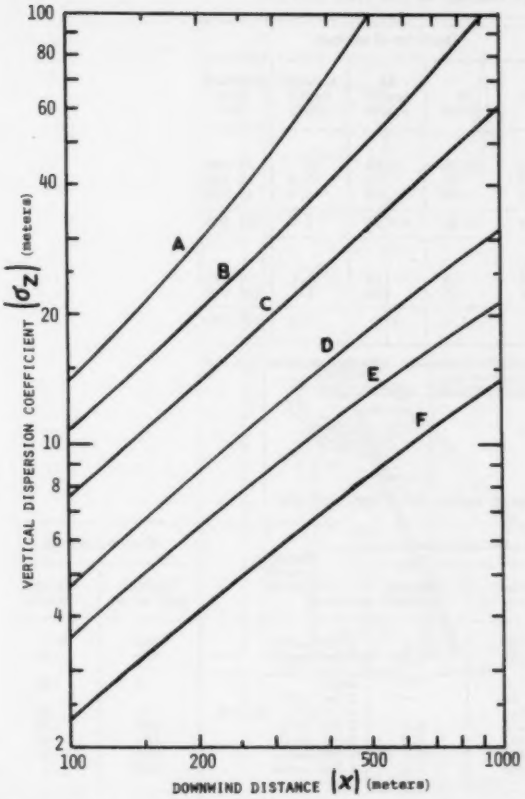

Figure 9. Vertical dispersion coefficients by atmospheric stability classes (after Pasquill and Gifford) (7)

Case study—the Vitro site

The data and computations which follow are presented as a case study to illustrate procedures for predicting radiation exposures that might be encountered as a result of commercial development of a uranium mill tailings pile. This case was selected because it involved a specific proposal by the Silvex Corporation of Salt Lake City to construct an automobile race track on the site of the abandoned tailings pile of the Vitro Chemical Corporation near Salt Lake City. The average radium concentration in this pile has been estimated to be 290 pCi/g.

The general layout of the tailings pile from the Vitro mill, and the location of the proposed Silvex Speedway, is shown in figure 10. The general wind pattern, as reported by Shearer and Sill (*8*), is shown on the site plan. The prevailing wind, occurring approximately half of the time, is from the south-southeast. The most frequent wind direction is from the northwest; it is referred to as the "Salt Lake City" wind, and occurs about 20 percent of the time. A "morning" wind from the south occurs somewhat less frequently.

The estimated distribution of tailings over the 93-acre site is listed in table 3. The source terms for calculating potential radiation exposures are contained in table 4. The gamma-ray exposure rate of 1.1 mR/h over the bare tailings was measured with CaF_2:Dy thermoluminescent dosimeters (*8*). The source used in the calibration of these dosimeters was not specified. The radon emanation rates were calculated in the manner previously presented.

Exposure calculations

The specific assumptions used in the calculation of radon and radon progeny concentrations also are shown in figure 10. The most important exposure location was assumed to be the proposed track. Since the largest source of radon lies to the southwest of the track, the SSE prevailing wind was assumed. The radon flux in the upwind area (cross-hatched) was assumed to be 350 pCi/m^2-s.

Because of a lack of specific meteorological data, three atmospheric stability conditions (B, D, and F), and three wind speeds for each stability class, were assumed. A frequency of occurrence, based upon generalizations from other locations, was assigned to each meteorological condition. Since the calculations were made only for the prevailing wind direction, the frequencies of occurrence were selected to produce a total of 100 percent, although the actual frequencies for this wind direction would be only 50 percent of the total. For the indicated wind direction, the mean source distance, x, is 1400 feet (460 meters).

The intermediate results obtained from the atmospheric dispersion and concentration calculations are shown in table 5. The calculated average radon concentration, for the stated assumptions, turned out to be 6.8 pCi/liter, com-

Table 3. Estimated distribution of tailings on old Vitro mill site

Area	Quantity of tailings				
	Acres	M (tons)	M (cubic yards)	Average depth (feet)	Exposed area (m^2)
Silvex proposal:					
Track	[a]13.5	0.33	0.13	14	21 000
North parking	[a]10.3	.27	.11	5.5	42 000
South parking	[a]10.1	.26	.10	5.5	41 000
Subtotal	33.9	0.86	[b]0.34	8.9	104 000
Other:					
Vacant (north)	12.5	.16	.06	3.1	72 000
South frontage	5.2				
M & R	41.4	.48	.20	3.1	167 000
Total	[b]93	[b]1.5	0.6	5.2	343 000

[a] Areas determined from architect's drawings for Silvex Speedway. All other numbers are estimates derived from (a) and (b) and from personal observations.
[b] Personal communication from Mr. Robert J. Catlin, USAEC, April 11, 1973.

Table 4. Radiation exposure source terms for Vitro mill site

Site area [a]	Average tailings depth (feet)	Exposed area (m^2)	Bare tailings exposures		Assumed earth cover	Covered tailings	
			Radon (pCi/m^2–s)	Gamma (mR/h)		Radon (pCi/m^2–s)	Gamma (mR/h)
Vacant (north)	3.1	51 000	380	1.1	1 foot earth	350	0.1
North parking	5.5	42 000	435	1.1	2 feet earth	360	.01
Track:							
Bowl	0	—	—	—	none	0	.01
Grandstands	14	—	—	—	2 feet earth + 9 inches concrete	<1	.01
Surroundings	14	21 000	455	1.1	2 feet earth	380	.01
South parking	5.5	41 000	435	1.1	2 feet earth	360	.01
South frontage	3.1	21 000	380	1.1	2 feet earth	310	.01
M & R	3.1	167 000	380	1.1	1 foot earth	350	.1

[a] Designated areas are as shown in figure 10.

Table 5. Calculations of average concentrations of radon and progeny

Radon flux, ϕ: 350 pCi/m^2–s
Source distance, X: 1400 feet or 460 m

Atmospheric stability class:	B, good dispersion			D, neutral			F, near stagnant		
Vertical dispersion coefficient, σ_z (at $X/2$):	23 m			9.5 m			4.5 m		
Wind speed, μ: (miles per hour)	6.7	13.4	20.0	4.5	9.0	13.5	2.2	4.5	6.7
(m/s)	3.0	6.0	9.0	2.0	4.0	6.0	1.0	2.0	3.0
Frequency of occurrence (assumed), f:	.10	.10	.05	.20	.20	.20	.05	.05	.05
Radon concentration:									
$C_i = (10^{-4})\ \phi x/u\sigma_z$: (pCi/liter)	2.3	1.2	.80	8.5	4.2	2.8	36	18	12
Contribution to annual average,									
$C_f = fC_i$: (pCi/liter)	.23	.12	.04	1.7	.84	.56	1.8	.90	.60
Radon progeny concentration:									
Ingrowth time, $x/2u$: (s)	77	38	26	115	58	38	230	115	77
(min)	1.3	.6	.4	1.9	1.0	.4	3.8	1.9	1.3
Progeny ingrowth fraction,									
WL per pCi Rn/liter: [$\times 10^4$]	2.8	1.3	1.0	4.0	2.2	1.0	7.6	4.0	2.8
$WL_i = (WL-1/pCi)C_i$: [$\times 10^4$]	6.4	1.6	.8	34	9.2	2.8	270	72	33
Contribution to annual average,									
$WL_f = fWL_i$: [$\times 10^4$]	.64	.16	.05	6.8	1.8	.56	14	3.6	1.7

Annual averages (calculated from above assumptions):
Radon, C(average) = ΣCf = 6.8 pCi/liter
Radon progeny, WL(average) = Σ WL_f = 0.0029 WL
Average radon progeny ingrowth = 0.0029/6.8 = 0.00043, or 4 percent of equilibrium.

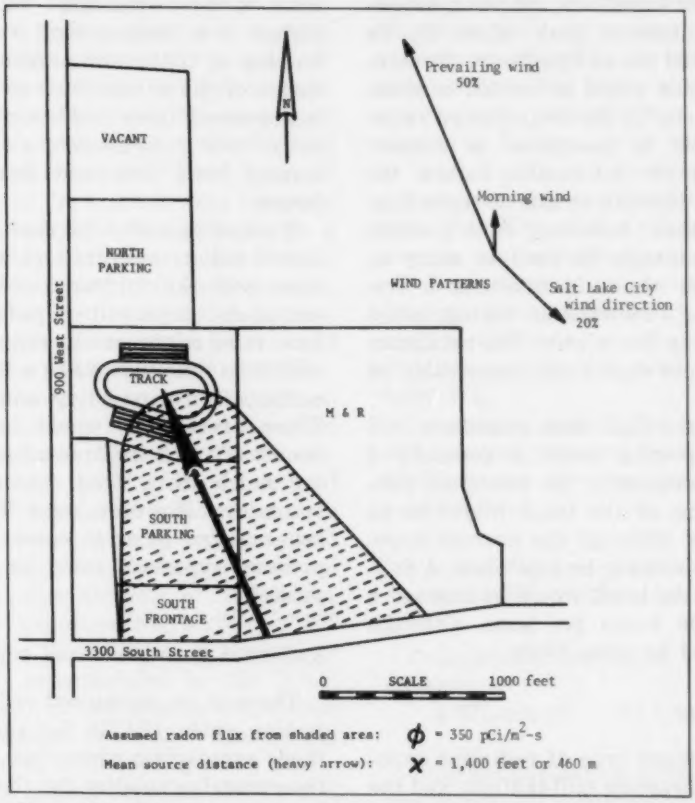

Figure 10. Radon source geometry for prevailing wind at proposed Silvex Speedway

pared with a measured value (*8*) of 10 pCi/liter. The calculated average concentration of radon progeny is 0.0029 WL.

At least two potential sources of error in the theoretical analysis of radon exposures should be noted:

(1) Errors in the assumed meteorological conditions. Although the mean wind speed used in the calculations (9 miles per hour) is essentially the same as that observed during the period of the radon measurements (*8*), the assumed dispersion conditions may not be adequately representative. Also, the use of only the prevailing wind direction in the calculations tends to produce an overestimate of the average radon concentration.

(2) Errors in the assumed radon flux. The radon emanation rate used in the calculations was based upon experimental data obtained with dry tailings. The radon flux can be lowered significantly if the tailings are soaked and/or covered with standing water.

Although the numerical values used in the calculations were carried to two or three figures, the resulting exposure estimates should be interpreted as valid only to one significant figure, with an estimated overall accuracy of approximately a factor of two.

Occupancy factors

Radiation protection guides for the general

public are always based on annual averages and not on instantaneous peak values. In the case of the proposed Silvex Speedway, the automobile racing season would be limited to about 5 months—primarily by the temperature range that is acceptable to spectators in outdoor grandstands. For the foreseeable future, the track proposed to schedule events no more than three nights a week; however, it is possible that it might eventually be used as many as six evenings each week. In addition, a few special events, e.g. snowmobile racing, could be scheduled during the winter. The maximum number of track use days could conceivably be 150 per year.

The average time that most spectators will remain at any sporting event is generally 4 hours or less. Consequently, the maximum public attendance time at the track might be as high as 600 hours, although the average exposure time would obviously be much less. A full-time employee at the track would be exposed a maximum of 2000 hours per year, although fewer hours would be more likely.

Enclosed structures

The most significant type of radiation exposure produced by uranium mill tailings, and the most difficult and costly to control, is the exposure to airborne radon progeny in enclosed spaces. If a structure is built in direct contact with tailings, it is possible for radon to diffuse directly from the tailings into the structure. If a structure is merely situated in an environment containing abnormally high atmospheric radon concentrations, the indoor concentration of radon will be essentially equal to the outdoor concentration.

The critical factor in determining the indoor radon progeny concentration, in addition to ascertaining the concentration of the radon, is the assessment of the mean residence time of the radon in the indoor atmosphere. In private homes, the typical air residence time falls in the range of 20 to 60 minutes. In commercial structures, the average time for one complete air exchange is frequently less than 20 minutes.

In the case of the proposed Silvex Speedway, the only enclosed areas would be the snack bars, the rest rooms, a press box and a club house. Each of these structures would have to be designed in a manner that would minimize the buildup of radon and progeny. The direct diffusion of radon into these structures from tailings beneath them could be minimized by using extra thick concrete floor slabs, or even multi-layered floors with radon barriers between the layers.

Even with radon barriers in the floors, the indoor radon concentrations would be in equilibrium with the outdoor concentrations. During occupancy, ingrowth of radon progeny might have to be minimized by reducing the mean air residence time indoors to a few minutes, or by continually recirculating and filtering the air. These precautions would be needed for the benefit of track employees who would be spending much more time indoors than the race spectators. However, since the situation could be evaluated prior to construction, the radon progeny exposures could be controlled appropriately.

Radiation dose limits and population risk

There is no recognized radioactivity concentration guide (RCG) for radon alone, nor is there a radiation protection guide (RPG) for the general population for the type of radiation exposure of concern here. However, there are three acceptable sources of recommended exposure limits from which inferences may be drawn. Each of the recommended exposure limits is based upon the dose to the respiratory tract from the alpha particles emitted by the short-lived progeny, but each is restricted to occupational exposures or to a special situation.

The ICRP (*9*) recommends a limit for continuous occupational exposure of 10 pCi of radon per liter of air, including all of the daughter products ordinarily found in unfiltered air. Depending upon the degree of equilibrium, this limit would be equivalent to 0.03 to 0.1 WL. The ICRP further recommends that the average permissible limit for the population at large should not exceed one-thirtieth of the continuous occupational value. Although the phrase "populations at large" is not precisely defined, the continuous public exposure limit recommended by the ICRP could be as low as 0.001 to 0.003 WL.

In connection with the anticipated remedial action program for buildings in Grand Junction, Colo. (where tailings had been used as construction fill), exposure guidelines were set by the U.S. Surgeon General (*10*). The Surgeon General's guidelines state that for an annual average exposure of less than 0.001 WL, no corrective action is indicated. This limit, of course, was set only for a preexisting exposure condition and is not directly applicable to a preplanned situation. However, if this limit is reduced by another factor of three to account for a general, as opposed to a limited, population, the annual average exposure limit would be equivalent to the ICRP value, or 0.003 WL.

The third exposure limit from which an inference may be drawn is that recommended by the Federal Radiation Council (*11*) and subsequently adopted by the U.S. Department of Labor. This limit applies to uranium miners and is expressed as an annual exposure limit of 4 WL-months per year. Since one month of occupational exposure consists of 173 hours, this is equal to an exposure-time product of 692 WL-hours per year. If this limit is reduced by the factor of 30 recommended by the ICRP, the resulting limit for the general population becomes, by inference, about 23 WL-hours per year. If this number is divided by 8766 hours/year, the average annual exposure limit would also be 0.003 WL.

Whether or not the occupational exposure limit for radon progeny inhalation should be reduced for the general population by the same factor as is applied to other kinds of radiation exposure is a matter of conjecture. In a comprehensive analysis of the incidence of lung cancer among uranium miners, Lundin et al. (*12*) found no indication of additional risk among miners having a cumulative exposure of less than 120 WL-months. Spread out over a nominal 70-year lifetime, rather than the 30 years used in deriving the occupational limit, the equivalent continuous exposure rate would be 0.03 WL. Radon progeny inhalation may, in fact, be one type of exposure for which there is a practical, if not theoretical, threshold for somatic biological effects.

Since all of the recommended exposure limits are for exposures in addition to natural background radiation, the natural concentrations of radon and its progeny must be considered. Eisenbud (*13*) states that "the average concentrations of radon in outdoor air may be taken to be in the range of 0.1 to 0.5 pCi/liter and the radon concentration inside buildings is somewhat higher and in round numbers may be taken as 0.5 pCi/liter on the average." In a study of radon in ground level air at Cincinnati, Ohio, Cox et al. (*14*) found that monthly average concentrations ranged from 0.1 to 1.5 pCi/liter during an 8-year period. Radon progeny concentrations in outdoor air, measured in Colorado, are typically in the range of 0.001 to 0.01 WL, with a mean of about 0.004 WL.

Conversion of all of the calculated exposures and inferred exposure limits to common units of WL-hours per year permits the following comparisons:

Naturally occurring radon progeny, outdoors:

$$0.004 \text{ WL} \times 8766 \text{ h/yr} = 35 \text{ WL-h/yr}$$

Occupational exposure limit for uranium miners:

$$4 \text{ WL-mo/yr} \times 173 \text{ h/mo} = 692 \text{ WL-h/yr}$$

Inferred population exposure limit (in addition to natural background):

$$0.003 \text{ WL} \times 8766 \text{ h/yr} = 26 \text{ WL-h/yr}$$

Full-time race track employees (maximum):

$$0.003 \text{ WL} \times 2000 \text{ h/yr} = 6 \text{ WL-h/yr}$$

Individual spectators (maximum):

$$0.003 \text{ WL} \times 600 \text{ h/yr} = 2 \text{ WL-h/yr}$$

At present there is no consensus on the appropriate conversion of working-level-months to man-rems or any other acceptable units of population dose commitment. However, it can be pointed out that if the track were to be completed as proposed, a few full-time employees would receive an exposure increment of 17 percent above the normal background exposure, corresponding to 1 percent of the occupational exposure limit, or 23 percent of the population exposure limit. A few thousand members of the general public could receive a maximum

additional exposure of 6 percent over the natural background or about 8 percent of the inferred population exposure limit.

Conclusions

For a depth of tailings of more than 1 or 2 feet thick, the gamma exposure rate over the tailings can be estimated from:

$$X\ (\mu R/h) \cong 2.5\ C_{Ra}\ (pCi/g)$$

Since C_{Ra} refers to a uniform concentration of radium in the tailings, it is essential that the value of C_{Ra} used in the above calculation be representative of the pile as a whole. Nonuniformity of the radium concentration would produce variations in measured exposure rates over the pile, but would have minimal effects on long-term average exposures.

The gamma-ray exposure rate over a tailings pile can be reduced to essentially that of the normal background by a cover of 2 feet of packed earth.

The radon emanation rate from the surface of a dry, bare tailings pile several feet thick can be estimated from:

$$\phi \propto (pCi/Rn/m^2\text{-}s) \cong 1.6\ C_{Ra}\ (pCi\ Ra/g)$$

Air concentrations of radon will be highest at the downwind edge of the pile. Earth covering will not be very effective for reducing radon emanation; 2 feet of earth would only reduce the radon flux to about three-fourths of its initial value.

The air concentration of radon progeny, the determinant factor for inhalation exposures, depends upon both the concentration and the mean age of the radon. For typical piles and wind conditions, the ingrowth of radon progeny near the pile will rarely reach 10 percent of equilibrium with the maximum radon concentration. It is also unlikely that the outdoor radon progeny concentration, on or near any tailings pile, would exceed an annual average of 0.003 WL in addition to natural background.

All of the radon and radon progeny concentrations presented in this paper were calculated on the basis of very conservative assumptions. To the extent possible, the calculations should be verified and refined. Air sampling for radon progeny concentrations, even for a relatively short time period, would provide some experimental evidence of actual conditions. A refinement of the theoretical analysis could also be made by using actual meteorological data for the local area instead of the assumed conditions used in the preceding calculations.

Enclosed structures should not be constructed on, or adjacent to, tailings piles without valid assurances that the occupancy factors will be quite low. Even then, special attention must be given to construction plans, and especially to ventilation, to assure low indoor air residence times during the periods of occupancy.

Until a permanent solution is found to the problem of abandoned uranium mill tailings, any plans for stabilization or utilization must be regarded as valid for only a short time period, e.g. 25–50 years. Although denial of all public access to a tailings pile may be a convenient and expedient action for a regulatory agency (*15–17*), it has not been conclusively demonstrated to be in the best public interest in all cases. If a productive use is proposed for an abandoned tailings location, a detailed analysis should be made of the potential radiation exposures involved. It is apparent that, in some circumstances, the radiation exposure risk would be extremely low and might well be completely offset by the benefits to be derived from productive use.

REFERENCES

(*1*) CULOT, M. V. J., H. E. OLSON and K. J. SCHIAGER. Radon progeny control in buildings, final report on EPA grant #R01–EC–00153 and AEC contract #AT(11–1)–2273. Colorado State University, Fort Collins, Colo. (May 1973).

(*2*) THROCKMORTON, C. R. Environmental gamma-ray flex analysis. Dissertation, Colorado State University, Fort Collins, Colo. (1973).

(*3*) MORGAN, K. Z. and J. E. TURNER. Principles of radiation protection. John Wiley and Sons, New York, N.Y. (1967).

(*4*) BUREAU OF RADIOLOGICAL HEALTH. Radiological health handbook, PHS Publication No. 2016. Department of Health, Education, and Welfare, Washington, D.C. (1970).

(5) EISENBUD, M. Environmental radioactivity, 2nd edition, quoting B. Hultqvist in studies on naturally occurring ionizing radiation. Kungliga Svenska Velenskapsakademiens Handlingar (1956). Academic Press, New York, N.Y. (1973) p. 189.

(6) EVANS, R. D. Engineers guide to the elementary behavior of radon daughters. Health Phys 17:229–252 (1969).

(7) TURNER, D. B. Workbook of atmospheric dispersion estimates. PHS Publication No. 999–AP–26. Department of Health, Education, and Welfare, Washington, D.C. (1967).

(8) SHEARER, Jr., S. D., and C. W. SILL. Evaluation of atmospheric radon in the vicinity of uranium mill tailings. Health Phys 17:77–88 (1969).

(9) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Report of Committee II on permissible dose for internal radiation, ICRP Publication No. 2 and Publication No. 6. Pergamon Press, New York, N.Y. (1969), (1962).

(10) SURGEON GENERAL, PUBLIC HEALTH SERVICE. Surgeon General's guidelines. Use of uranium mill tailings for constructive purposes. Hearings before the Subcommittee on Raw Materials of the Joint Committee on Atomic Energy, October 28 and 29, 1971 (1971) pp. 52–54.

(11) FEDERAL RADIATION COUNCIL. Radiation protection guidance for federal agencies, Federal Register, Vol. 34, No. 10 (1969) p. 576.

(12) LUNDIN, F. E., J. K. WAGONER and V. E. ARCHER. Radon daughter exposure and respiratory cancer quantitative and temporal aspects. NIOSH-NIEHS Joint Monograph No. 1, Department of Health, Education, and Walfare, Washington, D.C. (1971).

(13) EISENBUD, M. Environmental radioactivity, 2nd edition, Academic Press, New York, N.Y. (1973).

(14) COX, W. M., R. L. BLANCHARD and B. KAHN. Relation of radon concentration in the atmosphere to total moisture detention in soil and atmospheric thermal stability. Symposium, Radionuclides in the Environment, American Chemical Society, Washington, D.C. (1970).

(15) COLORADO DEPARTMENT OF HEALTH. Rules and regulations pertaining to radiation control; part VIII—regulations requiring stabilization of uranium and thorium mill tailings piles (radiation regulation no. 2, adopted December 12, 1966) Denver, Colo. (1970).

(16) ENVIRONMENTAL PROTECTION AGENCY. Model tailings regulation. Presented at the Seventh Session, Conference on the Colorado River Basin, February 15–16, 1972, EPA Region VIII, Denver, Colo.

(17) U.S. ATOMIC ENERGY COMMISSION. Fuels and materials guide: stabilization, maintenance and long term control of uranium mill tailings retention systems. Regulatory guide 3.11, directorate of regulatory standards, USAEC, Washington, D.C. (draft—January 1973).

SECTION I. MILK AND FOOD

Milk Surveillance, February 1974

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption readily can be obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, Public Health Service, consists of 65 sampling stations: 63 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Networks (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks reporting presently in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostron-

Figure 1. Milk sampling networks in the Western Hemisphere

tium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963-March 1966 (*3*) and are used for general radiation calculations.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, first it was necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Research and Development Program conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been previously outlined (*4*).

The most recent study was conducted during June 1972 with 37 laboratories participating in an experiment on a milk sample containing known concentrations of iodine-131, cesium-137, strontium-89, and strontium-90 (*5*). Of the 18 laboratories producing data for the network reports in *Radiation Data and Reports*, 14 participated in the study.

The accuracy results of this study for these 14 laboratories are shown in table 1. The accuracy of the cesium-137 measurements continues to be excellent as in previous experiments. However, both the accuracy and precision need to be improved for iodine-131, strontium-89, and strontium-90 which could probably be accomplished through recalibration.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The fre-

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration		Number of laboratories in each category				Experimental 2σ error (pCi/liter)
		Acceptable [a]	Warning level [b]	Unacceptable [c]	Total	
Iodine-131:	(96 or 99 pCi/liter)	7 (58%)	1 (8%)	4 (33%)	12	6
	(438 or 484 pCi/liter)	11 (85%)	0	2 (15%)	13	25 or 28
Cesium-137:	(53 or 54 pCi/liter)	11 (92%)	0	1 (8%)	12	6
	(295 or 303 pCi/liter)	11 (85%)	2 (15%)	0	13	17
Strontium-89:	(29 or 30 pCi/liter)	9 (82%)	0	2 (18%)	11	6
	(197 or 201 pCi/liter)	3 (33%)	1 (11%)	5 (56%)	9	11 or 12
Strontium-90:	(32.1 or 32.4 pCi/liter)	4 (33%)	4 (33%)	4 (33%)	12	1.9
	(150.5 or 151.2 pCi/liter)	6 (55%)	0	5 (45%)	11	8.7

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

quency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and generally is increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*6*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*6*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases, the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below those practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error of precision expressed as pCi/liter or percent in a given concentration range also has been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the United States data on radioactivity in milk in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions was presented in the February 1973 issue of *Radiation Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are reported routinely in *Radiation Data and Reports.* The relationship between the PMN stations and the State stations is shown in

Table 2. Concentrations of radionuclides in milk for February 1974 and 12-month period March 1973 through February 1974

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
UNITED STATES:						
Ala:	Montgomery*	P	NA	4	0	3
Alaska:	Palmer*	P	NA	4	0	1
Ariz:	Phoenix*	P	NA	0	0	0
Ark:	Little Rock*	P	NA	11	0	1
Calif:	Los Angeles*	P	NA	0	0	0
	Sacramento*	P	NA	1	0	0
	San Francisco*	P	NA	0	0	0
	Del Norte	P	NA		NA	
	Fresno	P	NA		NA	
	Humboldt	P	NA		NA	
	Los Angeles	P	NA		NA	
	Mendocino	P	NA		NA	
	Sacramento	P	NA		NA	
	San Diego	P	NA		NA	
	Santa Clara	P	NA		NA	
	Shasta	P	NA		NA	
	Sonoma	P	NA		NA	
Colo:	Denver*	P	NA	3	[d] 0	0
	East	R	NS	NA	NS	23
	Northeast	R	NS	NA	NS	0
	Northwest	R	NS	NA	NS	2
	South Central	R	NS	NS	NS	NS
	Southeast	R	NS	NA	NS	0
	Southwest	R	NA	NA	[d] 0	0
	West	R	NS	NA	NS	0
Conn:	Hartford*	P	NA	4	0	2
	Central	P	NA		NA	
Del:	Wilmington*	P	NA	6	0	1
D.C:	Washington*	P	NA	3	0	0
Fla:	Tampa*	P	NA	4	17	24
	Central	R	6	5	19	24
	North	R	7	6	13	15
	Northeast	R	6	6	27	26
	Southeast	R	5	5	68	48
	Tampa Bay area	P	4	5	18	27
	West	R	NA	8	NA	8
Ga:	Atlanta*	P	NA	4	0	3
Hawaii:	Honolulu*	P	NA	0	0	0
Idaho:	Idaho Falls*	P	NA	3	0	0
Ill:	Chicago*	P	NA	5	0	0
Ind:	Indianapolis*	P	NA	5	0	2
	Central	P	4	5	0	6
	Northeast	P	6	5	0	10
	Northwest	P	7	7	0	9
	Southeast	P	5	6	0	8
	Southwest	P	6	7	0	6
Iowa:	Des Moines*	P	NA	4	0	0
	Des Moines	P	5	5	0 (3)	0
	Iowa City	P	5	5	0	0
	LeMars	P	4	4	0	0
	Little Cedar	P	7	6	0	0
Kans:	Wichita*	P	NA	5	0	1
	Coffeyville	P	7	6	0	7
	Dodge City	P	4	4	0	6
	Falls City, Nebr	R	NS	6	NS	7
	Hays	P	7	6	0	5
	Kansas City	P	3	4	0	6
	Topeka	P	6	6	0	5
	Wichita	P	4	6	20	8
Ky:	Louisville*	P	NA	5	0	1
La:	New Orleans*	P	NA	7	0	1
Maine:	Portland*	P	NA	4	0	12
Md:	Baltimore*	P	NA	6	0	3
Mass:	Boston*	P	NA	7	0	8
Mich:	Detroit*	P	NA	6	0	3
	Grand Rapids*	P	NA	7	0	1
	Bay City	P	10	11	0	1
	Charlevoix	P	11	9	7	2
	Detroit	P	9	8	0	0
	Grand Rapids	P	22	12	0	3
	Lansing	P	11	11	0	3
	Marquette	P	18	11	6	7
	Monroe	P	7	13	0	1
	South Haven	P	21	14	3	3
Minn:	Minneapolis*	P	NA	7	0	1
	Bemidji	P	6	6	0	0
	Duluth	P	13	16	12	23
	Fergus Falls	P	5	5	0	0
	Little Falls	P	6	16	0	23
	Mankato	P	5	5	0	0
	Marshall	P	0	3	0	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for February 1974 and 12-month period March 1973 through February 1974—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
Minn:	Minneapolis	P	9	8	0	0
	Rochester	P	3	6	0	0
Miss:	Jackson[c]	P	NA	8	0	6
Mo:	Kansas City[c]	P	NA	4	0	0
	St. Louis[c]	P	NA	8	0	1
Mont:	Helena[c]	P	NA	2	0	0
Nebr:	Omaha[c]	P	NA	2	0	0
Nev:	Las Vegas[c]	P	NA	5	0	0
N.H:	Manchester[c]	P	NA	6	0	7
N.J:	Trenton[c]	P	NA	5	0	1
N. Mex:	Albuquerque[c]	P	NS	0	NS	0
N.Y:	Buffalo[c]	P	NA	5	0	3
	New York City[c]	P	NA	4	0	2
	Syracuse[c]	P	NA	6	0	1
	Albany	P	4	4	0	0
	Buffalo	P	2	4	0	0
	Massena	P	9	7	16	10
	New York City	P	4	7	0	0
	Syracuse	P	2	5	NA	0
N.C:	Charlotte[c]	P	NA	7	0	4
N. Dak:	Minot[c]	P	NA	6	0	0
Ohio:	Cincinnati[c]	P	NA	5	0	3
	Cleveland[c]	P	NA	6	0	2
Okla:	Oklahoma City[c]	P	NA	3	0	0
Oreg:	Portland[c]	P	NA	4	0	1
	Baker	P	NA	NA	0	1
	Coos Bay	P	NA	NA	0	1
	Eugene	P	NA	NA	0	0
	Medford	P	NA	NA	0	0
	Portland composite	P	NA	NA	0	1
	Portland local	P	NA	NA	0	2
	Redmond	P	NA	NA	0	0
	Tillamook	P	NA	NA	0	4
Pa:	Philadelphia[c]	P	NA	5	0	1
	Pittsburgh[c]	P	NA	9	0	3
	Dauphin	P	5	5	0	0
	Erie	P	7	7	0	0
	Philadelphia	P	5	4	0	0
	Pittsburgh	P	6	5	0	0
R.I:	Providence[c]	P	NA	4	0	4
S.C:	Charleston[c]	P	NS	5	NS	6
	Chapin	R	NS	8	NS	9
	Clemson	R	8	8	5	10
	Columbia	R	NS	8	NS	9
	Fairfield	R	NS	7	NS	12
	Hartsville-02	R	6	6	10	10
	Hartsville-03	R	14	15	13	13
	Lee County	R	NS	0	NS	14
	Oconee County	R	7	7	4	6
	Pickens	R	NS	7	4	6
	Williston	R	NS	7	NS	17
	Winnsboro	R	NS	7	NS	17
	York-01	R	7	7	6	6
	York-02	R	5	5	0	0
S. Dak:	Rapid City[c]	P	NS	6	0	1
Tenn:	Chattanooga[c]	P	NA	6	0	1
	Knoxville[c]	P	NA	0	0	0
	Memphis[c]	P	NA	6	0	2
	Chattanooga	P	NA	7	0	5
	Clinton	R	6	6	0	5
	Fayetteville	R	8	7	0	5
	Kingston	R	6	7	0	3
	Knoxville	P	5	5	0	4
	Lawrenceburg	R	6	6	0	4
	Nashville	P	NA	5	0	2
	Pulaski	R	5	6	0	2
	Sequoyah	R	NS	9	NS	5
Tex:	Austin[c]	P	NA	0	0	0
	Dallas[c]	P	NA	4	0	0
Utah:	Salt Lake City[c]	P	NA	2	0	0
Vt:	Burlington[c]	P	NA	4	0	5
Va:	Norfolk[c]	P	NA	6	0	1
Wash:	Seattle[c]	P	NA	1	0	0
	Spokane[c]	P	NA	5	0	0
	Benton County	R	NS	0	NS	0
	Franklin County	R	0	0	0	0
	Longview	R	6	5	16	7
	Sandpoint, Idaho	R	4	5	0	1
	Skagit County	R	3	4	0	0
W. Va:	Charleston[c]	P	NA	7	0	2
Wisc:	Milwaukee[c]	P	NA	4	0	1
Wyo:	Laramie[c]	P	NA	1	0	1

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for February 1974 and 12-month period March 1973 through February 1974—continued

Sampling location		Type of sample [a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average [b]	12-month average	Monthly average [b]	12-month average
CANADA:						
Alberta:	Calagary	P	NA		5	7
	Edmonton	P	NA		6	11
British Columbia:	Vancouver	P	NA		9	12
Manitoba:	Winnipeg	P	NA		9	9
New Brunswick:	Moncton	P	NA		7	9
Newfoundland:	St. John's	P	NA		8	15
Nova Scotia:	Halifax	P	NA		6	9
Ontario:	Ottawa	P	NA		4	5
	Sault Ste. Marie	P	NA		9	15
	Thunder Bay	P	NA		8	10
	Toronto	P	NA		5	5
	Windsor	P	NA		4	5
Quebec:	Montreal	P	NA		5	7
	Quebec	P	NA		10	12
Saskatchewan:	Regina	P	NA		5	7
	Saskatoon	P	NA		5	7
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal[c]	P	NS	0	NS	9
Chile:	Santiago	P	2	0	0	0
Colombia:	Bogota	P	2	1	0	0
Ecuador:	Guayaquil	P	0	1	0	0
Jamaica:	Mandeville	P	NS	2	NS	23
Puerto Rico:	San Juan[c]	P	NA	3	0	2
Venezuela:	Caracas	P	0	1	0	2
PMN network average[e]			NA	4	0	2

[a] P, pasteurized milk.
R, raw milk.
[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a month period, the number of samples in the monthly average is given in parentheses.
[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.
[d] The practical reporting level for this network differs from the general ones given in the text. Sampling results for these networks were equal to or less than the following practical reporting levels:
Cesium-137: Colorado—25 pCi/liter; Oregon—15 pCi/liter.
[e] This entry gives the average radionuclide concentrations for the Pasteurized Milk Network stations denoted by footnote [c].
NA, no analysis.
NS, no sample collected.

figure 2. The first column in table 2 under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90 and cesium-137 for February 1974 and the 12-month period, March 1973 to February 1974. Except where noted, the monthly

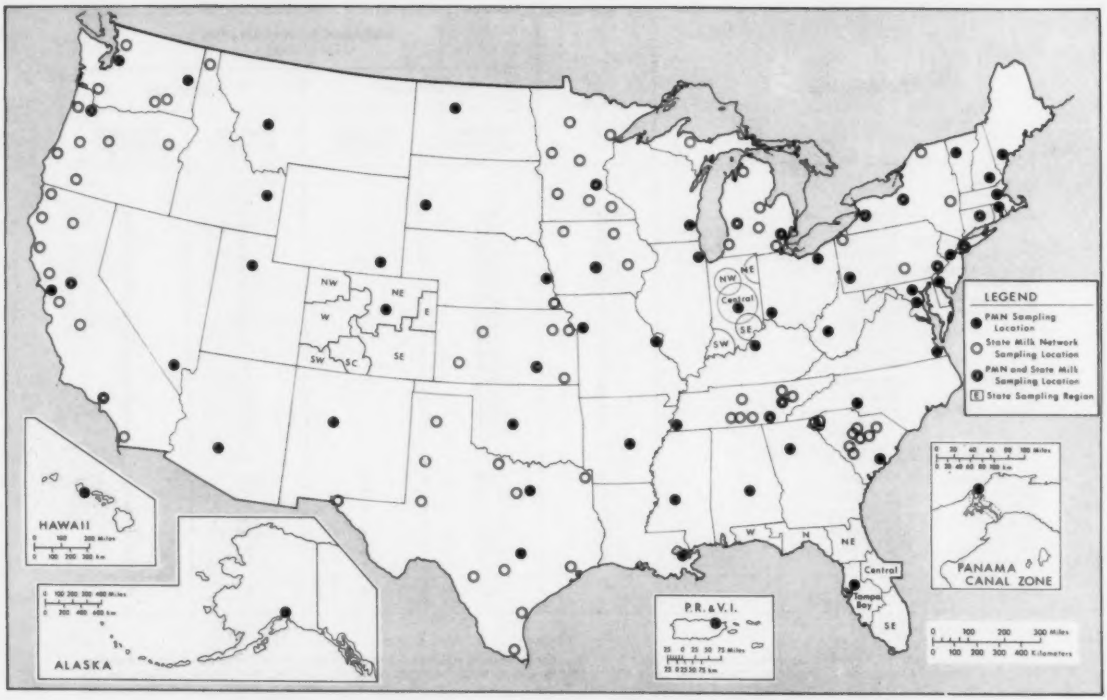

Figure 2. State and PMN milk sampling stations in the United States

average represents a single sample for the sampling station. Strontium-89, iodine-131, and barium-140 data have been omitted from table 2 since levels at all of the stations for February 1974 were below the respective practical reporting levels.

Strontium-90 monthly averages ranged from 0 to 22 pCi/liter in the United States for February 1974 and the highest 12-month average was 16 pCi/liter (Duluth and Little Falls, Minn.) representing 8.0 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to 68 pCi/liter in the United States for February 1974, and the highest 12-month average was 48 pCi/liter (Southeast Florida) representing 1.3 percent of the value derived from the recommendations given in the Federal Radiation Council report.

The Office of Radiation Programs is in the process of modifying the milk program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data from their milk surveillance networks:

Radiologic Health Section
Environmental Control Component
California Department of Health

Radiation Protection Bureau
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Laboratory Division
Connecticut Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Division of Radiological Health
South Carolina Department of Health and Environmental Control

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Unit
Health Services Division
Washington Department of Social and Health Services

REFERENCES

(*1*) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER, and K. H. LEWIS. The occurrence of strontium-90, iodine-131, and other radionuclides in milk, May 1957 through April 1958. Amer J Pub Health 49:225 (February 1969).

(*2*) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*3*) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk surveillance. Radiol Health Data Rep 9:730–746 (December 1968).

(*4*) ROSENSTEIN, M. and A. S. GOLDIN. Statistical technics for quality control of environmental radioassay. Health Lab Sci 2:93 (April 1965).

(*5*) BARATTA, E. J. and F. E. KNOWLES, JR. Interlaboratory study of iodine-131, cesium-137, strontium-89, and strontium-90 measurements in milk, June 1972, Technical experiment 72 MKAQ–1. Analytical Quality Control Service, Office of Radiation Programs, EPA, Washington, D.C. 20460 (December 1972).

(*6*) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiation Data and Reports* are as follows:

Program	Period reported	Issue
California Diet	July 1971–December 1972	February 1974
Carbon-14 in Total Diet and Milk	1972–1973	November 1973
Strontium-90 in Tri-City Diets	1972	December 1973

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*) set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1000 pCi/liter gross beta radioactivity, except when additional analysis indicates that the concentrations of radionuclides present are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiation Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	1971 and 1972	November 1973
Colorado River Basin	1968	March 1972
Community Water Supply Study	1969	September 1972
ERAMS Surface Water and Drinking Water Components	October–December 1973	June 1974
Florida	1970	April 1974
Interstate Carrier Drinking Water	1971	May 1972
Kansas	1971	February 1973
Minnesota	July 1971–June 1972	March 1974
New York	January–December 1972	June 1974
Radiostrontium in Tap Water, *HASL*	January–December 1972	December 1973
Washington	July 1970–June 1971	August 1973

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President. September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Radioactivity in North Carolina Surface, Cistern, and Saline Waters, 1971[1]

Sanitary Engineering Division
Radiological Health Section
North Carolina State Board of Health[2]

The North Carolina State Board of Health maintains an Environmental Radiation Surveillance Network to monitor radioactivity in selected media throughout the State. The Program is administered by the Radiological Health Section of the Sanitary Engineering Division.[2] Sample analysis is provided by the Environmental Sciences Section of the Laboratory Division. The Public Health Statistics Section of the Epidemiology Division provides assistance in certain data processing activity, while computer services are obtained through the Systems Management Division of the Department of Administration. Environmental sample collection is performed primarily by the staffs of municipalities and local health departments.

The program started with the surveillance of 147 sources of untreated surface waters. These supplies were selected as being representative of water quality in the many river basins of the State. Sample collection was achieved through close cooperation with municipalities and local health departments.

The program has changed through the years as technological advances in instrumentation made it possible to monitor more facets of the environment. In July 1962, cistern water samples from Ocrocoke Island were added to the surveillance program. In January 1963, airborne particulates, rainfall, and dustfall samples were collected on a routine sampling schedule over the State. The surface water program was modified to include treated water assays. Public ground water supplies also were added to the sampling program during this period.

Surface water

Grab samples of both treated and untreated surface water are taken on a monthly basis at nine water treatment plants. These stations

[1] Summarized from "Environmental Radiation Surveillance in North Carolina, 1971."
[2] As of April 1974, Radiation Protection Branch, Division of Facility Services, North Carolina Department of Human Resources.

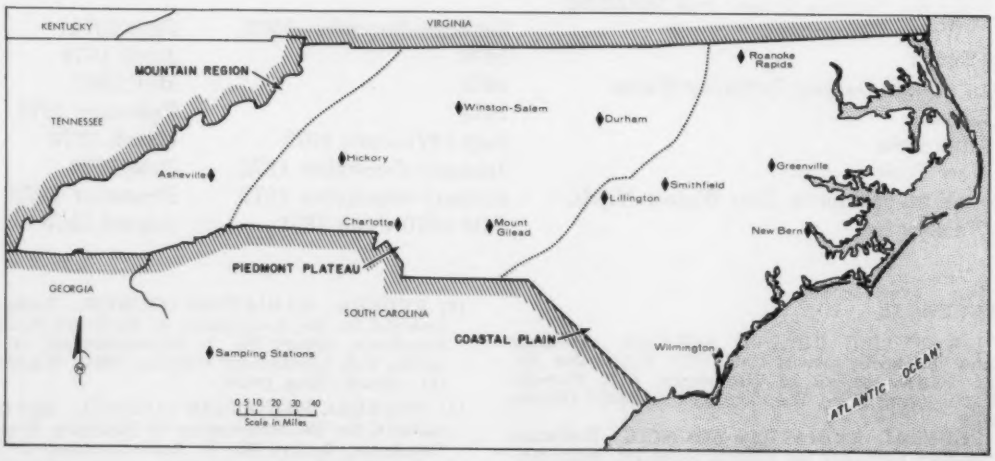

Figure 1. North Carolina water sampling stations, 1971

were selected to obtain samples from the State's major drainage districts with the French-Broad, Catawba, Yadkin, Cape Fear, Neuse, and Tar-Pamlico river basins being represented.

The samples routinely are collected in 1-gallon (polyethylene) containers by the water plant operator or chemist and mailed to the State laboratory for analysis. Additional samples can be collected as needed. These stations are shown in figure 1.

Untreated water samples are acidified with hydrochloric acid to prevent loss of activity through precipitation and/or adhesion. The samples then are transferred to 3½-liter polyethylene Marinelli beakers for gamma scans.

After scanning, 1 liter is filtered through Whatman No. 12 folded filter paper. The filter paper, containing the suspended solids, is ashed in a muffled furnace at 600 degrees Celsius. The residue then is transferred to a tared planchet, dried, weighed, and submitted for gross alpha and beta counting (*1*).

The filtrate is separated by precipitation into dissolved sulfates and dissolved carbonates, plancheted, and submitted for gross beta counting (*1*).

If the total gross beta is greater than 5 pCi/liter, a strontium-89 and strontium-90 determination is performed (*1*).

As with the untreated surface water, treated water samples are acidified with 2 milliliters of hydrochloric acid to prevent loss of activity through precipitation and adhesion. These samples are transferred to 3½-liter polyethylene Marinelli beakers for gamma scans. The suspended material is prepared for gross alpha and beta counting in the same manner as untreated water samples. The filtrate carefully is evaporated to determine the gross alpha and beta activity of the dissolved solids. As before, if

Table 1. Gross beta radioactivity in North Carolina raw surface water, January-December 1971

Month (1971)	Raw water (pCi/liter)										
	Asheville	Hickory	New Bern	Winston-Salem	Roanoke Rapids	Lillington	Smithfield	Charlotte	Mt. Gilead	Wilmington	Greenville
January	ND	4.00			4.40	ND	ND	ND	ND	ND	ND
February	<3.0	4.00		14.50	ND	7.30	ND	3.30	4.10	7.00	9.40
March	<3.0	ND		<3.0	5.10	5.60	7.40	3.30	5.20	6.80	5.60
April	<3.0	<3.0		<3.0	4.60	7.50	4.50	3.90	5.00	ND	5.30
May	<3.0	3.70		10.30	ND	7.20	7.90	4.80	4.90	6.10	8.40
June	<3.0	ND	9.50	5.80	ND	6.10	5.70	<3.0	6.50	7.30	7.30
July	<3.0	<3.0	21.70	4.40	4.30	6.00	6.50	<3.0	4.50	6.70	6.90
August	<3.0	<3.0	23.10	3.10	4.20	6.90	5.70	<3.0	4.20	4.30	6.10
September	<3.0	ND	7.20	<3.0	ND	7.00	6.20	<3.0	3.90	4.20	6.20
October	<3.0	<3.0	5.40	3.70	3.70	5.80	5.70	<3.0	4.90	4.40	6.50
November	<3.0	3.10	6.20	<3.0	ND	4.10	ND	ND	4.60	34.80	ND
December	ND	<3.0	ND	<3.0	ND	4.30	5.00	<3.0	3.10	3.00	8.70

ND, Nondetectable.

Table 2. Gross beta radioactivity in North Carolina treated surface water, January-December 1971

Month (1971)	Treated water (pCi/liter)									
	Asheville	Hickory	Winston-Salem	Roanoke Rapids	Lillington	Smithfield	Charlotte	Mt. Gilead	Wilmington	Greenville
January	ND	<3.0	ND	7.30	ND	ND	ND	ND	ND	ND
February	<3.0	<3.0	4.00	ND	5.00	ND	3.80	3.10	3.70	6.10
March	<3.0	ND	<3.0	3.80	4.20	5.10	3.50	3.30	5.20	4.80
April	<3.0	<3.0	<3.0	<3.0	3.80	4.20	<3.0	3.50	3.90	3.60
May	<3.0	3.50	23.90	ND	5.50	5.10	3.60	3.50	5.00	5.00
June	<3.0	ND	<3.0	ND	7.40	4.40	<3.0	4.20	4.70	5.60
July	<3.0	<3.0	<3.0	ND	8.10	6.00	<3.0	4.40	4.30	5.20
August	<3.0	<3.0	3.40	3.70	5.50	5.90	<3.0	4.30	3.80	5.10
September	<3.0	ND	<3.0	ND	ND	5.50	<3.0	<3.0	4.20	5.70
October	<3.0	<3.0	<3.0	3.80	4.90	5.10	<3.0	3.70	4.10	4.90
November	<3.0	<3.0	<3.0	ND	4.00	ND	<3.0	3.60	3.90	ND
December	ND	<3.0	ND	ND	3.80	3.70	<3.0	<3.0	3.20	4.00

ND, nondetectable.

the total gross beta is greater than 5 pCi/liter, a strontium-89 and strontium-90 determination is performed.

A summary of surface water data is provided in table 1 (raw) and table 2 (treated).

Sewage treatment plant effluent water

Samples are taken on a monthly basis at three sewage treatment plants. They routinely are collected by plant personnel in 1-gallon polyethylene containers and mailed to the State laboratory for analysis. Additional samples can be collected if needed. Samples are prepared in the same manner as untreated surface water.

A summary of sewage treatment plant effluent water data is provided in table 3.

Saline water

One gallon of saline water is collected and processed the same as the untreated surface samples. However, because of high solids content, only 200 milliliters is filtered for alpha and beta measurement. The gross alpha and beta radioactivity in saline water for Morehead City for July was <1.0 and 269.0 pCi/liter respectively.

Bottom silt

Bottom sediment was collected in 1-liter samples. The silt is transferred to a 1-liter polyethylene Marinelli beaker for gamma analysis after rocks and other unwanted materials are removed. The sample is then ashed at 560 degrees centigrade for 36 hours, weighed, plancheted, and submitted for gross alpha and beta counting.

The gross alpha and beta radioactivity in bottom silt (Morehead City) for July was <1.0 and 5150 pCi/liter, respectively.

Summary of results

All environmental radioactivity concentrations during 1971 were well below the limits set for protection of the public's health. There were no significant or unexpected differences between these results and the 1968–1970 results.

Detectable quantities of fission products were observed in many samples during the reporting period. Increases in fission product inventories correlated well with reported nuclear detonations.

The continued demonstration of the ability of the network to detect low levels of radioactivity ensures that higher levels which could affect public health will not go unnoticed.

REFERENCE

(1) PORTER, C. R., R. J. AUGUSTINE, J. M. MATUSEK, Jr., and M. W. CARTER. Procedures for determination of stable elements and radionuclides in environmental samples, PHS Publication No. 999–RH 10. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (January 1965).

Previous coverage in *Radiation Data and Reports:*

Period	Issue
1968–1970	September 1972

Table 3. Gross alpha and beta radioactivity in sewage treatment effluent water, North Carolina, January-December 1971

1971	Concentration (pCi/liter)					
	Durham		Winston-Salem		Charlotte	
	Gross alpha	Gross beta	Gross alpha	Gross beta	Gross alpha	Gross beta
January	ND	ND	ND	ND	ND	ND
February	<1.0	21.7	<1.0	58.1	ND	14.8
March	<1.0	21.9	<1.0	42.4	<1.0	12.3
April	<1.0	11.0	<1.0	56.3	<1.0	10.9
May	<1.0	10.7	<1.0	49.6	<1.0	9.10
June	<1.0	14.8	<1.0	47.9	<1.0	12.1
July	<1.0	14.9	<1.0	6.20	<1.0	10.9
August	<1.0	28.9	ND	ND	<1.0	12.8
September	<1.0	26.1	<1.0	37.6	<1.0	8.90
October	<1.0	13.1	<1.0	43.6	<1.0	9.20
November	<1.0	7.60	ND	ND	<1.0	12.6
December	<1.0	29.0	<1.0	45.8	ND	ND

ND, nondetectable.

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were covered previously in *Radiation Data and Reports.*

Network	Period	Issue
Fallout in the United States and other areas, *HASL*	1971	August 1973
Krypton–85 in air	July 1970–1972	March 1974
Mexican air monitoring	July–December 1973	May 1974
Plutonium in airborne particulates	April–June 1973	June 1974
Surface air sampling program, 80th Meridian Network, *HASL*	1971	September 1973

1. Radiation Alert Network February 1974

Eastern Environmental Radiation Facility
Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN). Samples are collected at 68 locations throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. The airborne particulate samples and precipitation samples are sent to the Eastern Environmental Radiation Facility for further analysis. All field estimate results are reported to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily measurements is available upon request from the Eastern Environmental Radiation Facility, Montgomery, Ala. 36109. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports*.

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate and laboratory techniques during February 1974.

The Office of Radiation Programs is in the process of modifying the air program to make it more responsive to potential sources of environmental radioactivity. These changes will be reflected in future articles.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, February 1974

Station location [a]		Number of samples	Gross beta radioactivity (pCi/m³)						Precipitation	
			5-hour field estimate			Laboratory measurement			Laboratory estimate of deposition	
			Maximum	Minimum	Average [b]	Maximum	Minimum	Average [b]	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	7	1	0	0	0.16	0.03	0.07	54	0.26
Alaska:	Anchorage	2	0	0	0	.04	.02	.03		
Calif:	Berkeley	8	1	0	0	.07	.03	.05	12	.05
	Los Angeles	8	2	0	1	.13	<.01	.07		
Colo:	Denver	8	1	0	0	.23	.04	.12	4	.05
Idaho:	Idaho Falls	8				.12	.03	.06	18	.12
Ind:	Indianapolis	8	0	0	0	.09	.03	.06		
Nev:	Las Vegas	8	1	0	1	.13	.05	.09	1	.07
N. Mex:	Santa Fe	8	1	0	0	.13	.07	.09		
N.Y:	Buffalo	8	0	0	0	.11	.04	.06	2	.02
N. Dak:	Bismarck	8	2	0	1	.08	.04	.06	8	.12
Ohio:	Columbus	7	0	0	0	.08	.06	.07		
Okla:	Oklahoma City	4	2	1	1	.09	.06	.07		
Oreg:	Portland	18	0	0	0	.05	<.01	.03		
Pa:	Harrisburg	17	1	0	0	.10	.03	.04		
S.C:	Columbia	8	1	0	0	.09	.05	.07	84	.45
Network summary		135	2	0	0	0.23	<0.01	0.07	23	0.14

[a] The remaining stations are on standby status.
[b] The monthly average is calculated by weighting the estimates of individual air samples with length of sampling period.

2. Air Surveillance Network February 1974

National Environmental Research Center—Las Vegas
Environmental Protection Agency

The Air Surveillance Network,[1] operated by the National Environmental Research Center—Las Vegas (NERC–LV), consists of 49 active and 72 standby sampling stations located in 21 western States (figures 2 and 3). The network is operated in support of nuclear testing sponsored by the U.S. Atomic Energy Commission (AEC) at the Nevada Test Site (NTS), and at any other designated testing sites.

The stations are operated by State health department personnel and by private individuals on a contract basis. All active stations are operated continuously with filters being exchanged after periods generally ranging from 48 to 72 hours. All samples are mailed to the NERC–LV unless special retrieval is arranged at selected locations in response to known releases of radioactivity from the NTS. A complete description of sampling and analytical procedures was presented in the February 1972 issue of *Radiation Data and Reports.*

Table 2 presents the average gross beta concentrations in air for each of the network stations. The minimum reporting concentration for gross beta activity is 0.1 pCi/m³. For reporting purposes, concentrations less than 1.0 pCi/m³ are reported to 1 significant figure, and those equal to or greater than 1.0 pCi/m³ are reported to 2 significant figures. For averaging purposes, individual concentration values less than the minimum detectable concentration (—0.03 pCi/m³ for a 700 m³ sample) are set equal to the minimum detectable concentration (MDC). Reporting and rounding-off conventions are as follows:

[1] This network is operated under a Memorandum of Understanding (No. AT (26–1)–539) with the Nevada Operations Office, U.S. Atomic Energy Commission.

Concentration (pCi/m^3)	Reported value of concentration above MDC (pCi/m^3)	Reported value of concentration below MDC (pCi/m^3)
<0.05	<0.1	<0.1
≥ 0.05 <0.15	0.1	<0.1
≥ 0.15	As calculated and rounded	$<$calculated MDC

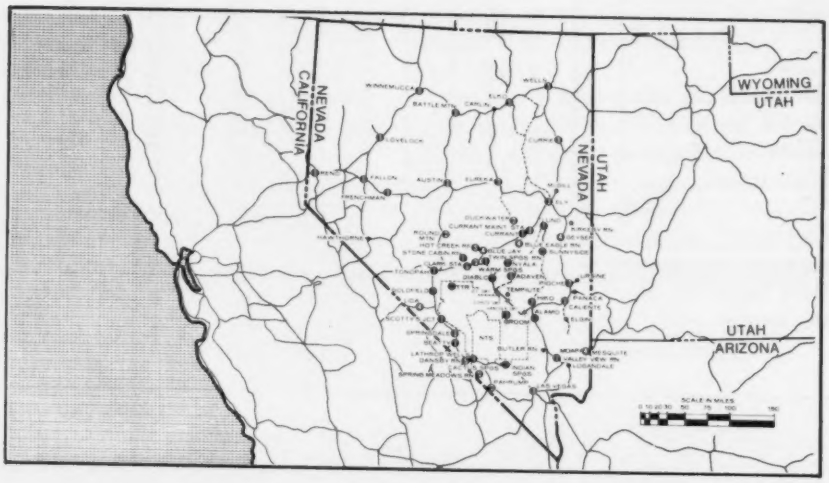

Figure 2. NERC-LV Air Surveillance Network stations in Nevada

Figure 3. NERC-LV Air Surveillance Network stations outside Nevada

As shown by table 2, the highest gross beta concentration within the network was 1.1 pCi/m³ at Geyser Ranch, Nev.

From gamma spectrometry results, fission products in varying combinations of zirconium-95, ruthenium-103 and cerium-141 were identified on filters collected in Nevada. The highest concentrations of these radionuclides, respectively, were 0.11 pCi/m³ (Blue Jay), 0.051 pCi/m³ (Groom Lake), and 0.035 pCi/m³ (Blue Jay). These radionuclides are attributed to annual worldwide fallout. No radionuclides were identified by gamma spectrometry on any charcoal cartridges during February.

Complete copies of this summary and listings of the daily gross beta and gamma spectrometry results are distributed to EPA Regional Offices and appropriate State agencies. Additional copies of the daily results may be obtained from the NERC/LV upon written request.

Table 2. Summary of gross beta radioactivity concentrations in air, February 1974

Location		Number of samples	Concentration (pCi/m³)		
			Maximum	Minimum	Average *
Ariz:	Kingman	12	0.4	<0.1	0.2
	Seligman	12	.3	<.1	.2
Calif:	Baker	10	.4	<.1	.2
	Barstow	12	.2	<.1	.1
	Bishop	12	.5	<.1	.3
	Death Valley Junction	12	.3	<.1	.2
	Furnace Creek	12	.2	<.1	.2
	Lone Pine	6	.3	.1	.2
	Needles	3	.2	.1	.2
	Ridgecrest	12	.2	<.1	.2
	Shoshone	12	.3	<.1	.2
Nev:	Alamo	12	.3	<.1	.2
	Austin	12	.3	<.1	.1
	Beatty	12	.2	<.1	.1
	Blue Eagle Ranch (Currant)	12	.3	<.1	.1
	Blue Jay	12	.4	<.1	.2
	Caliente	12	.2	<.1	.1
	Currant Ranch	12	.3	<.1	.1
	Diablo	12	.3	.1	.2
	Duckwater	12	.2	<.1	.1
	Ely	12	.2	<.1	.1
	Eureka	12	.3	<.1	.1
	Fallini's Twin Springs Ranch	12	.3	<.1	.2
	Geyser Ranch (Pioche)	7	1.1	.1	.2
	Goldfield	12	.2	<.1	.1
	Groom Lake	9	.3	<.1	.2
	Hiko	12	.3	<.1	.2
	Indian Springs	12	.4	.1	.1
	Las Vegas	17	.3	<.1	.2
	Lathrop Wells	12	.3	<.1	.1
	Lida	12	.3	<.1	.1
	Lund	12	.3	<.1	.1
	Mesquite	12	.3	<.1	.1
	Nyala	12	.2	<.1	.1
	Pahrump	13	.3	<.1	.2
	Pioche	12	.2	<.1	.1
	Round Mountain	12	.2	<.1	.1
	Scotty's Junction	12	.3	<.1	.2
	Stone Cabin Ranch	12	.2	.1	.2
	Sunnyside	12	.2	<.1	.1
	Tonopah	12	.2	<.1	.1
	Tonopah Test Range	10	.2	<.1	.1
	Warm Springs	11	.3	<.1	.1
	Warm Springs Ranch	12	.3	<.1	.1
Utah:	Cedar City	5	.2	<.1	.1
	Delta	12	.2	<.1	.1
	Garrison	12	.3	<.1	.1
	Milford	8	.2	<.1	.1
	St. George	12	.3	<.1	.2

* Individual values less than the minimum detectable concentration (MDC) are set equal to the MDC for averaging. A monthly average less than the minimum reportable value of 0.1 pCi/m³ is reported a <0.1.

3. Canadian Air and Precipitation Monitoring Program,[2] February 1974

Radiation Protection Bureau
Department of National Health and Welfare

The Radiation Protection Bureau of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 4), where the sampling equipment is operated by personnel from the Atmospheric Environment Service of the Department of the Environment. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

[2] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for February 1974 are presented in table 3.

Table 3. Canadian gross beta radioactivity in surface air and precipitation, February 1974

Location	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	4	0.08	0.01	0.05	20.3	0.4
Coral Harbour	4	.06	.04	.05	25.1	.2
Edmonton	4	.07	.05	.06	13.9	.5
Ft. Churchill	4	.07	.03	.05	38.2	.2
Fredericton	3	.05	.04	.05	22.1	1.6
Goose Bay	4	.04	.02	.03	5.7	.4
Halifax	4	.07	.04	.06	13.7	2.4
Inuvik	2	.03	.01	.02	NS	NS
Montreal	4	.03	.01	.02	17.9	.7
Moosonee	4	.06	.04	.05	NS	NS
Ottawa	4	.04	.01	.03	25.0	1.1
Quebec	4	.04	.03	.04	NS	NS
Regina	3	.07	.06	.07	10.0	.3
Resolute	4	.06	.04	.05	115.0	.4
St. John's, Nfld.	4	.02	.01	.02	38.5	2.8
Saskatoon	4	.06	.04	.05	30.8	.3
Sault Ste. Marie	4	.05	.04	.05	17.6	.6
Thunder Bay	4	.05	.03	.04	NS	NS
Toronto	NS				29.4	1.6
Vancouver	4	.03	.02	.03	11.2	1.2
Whitehorse	4	.06	.02	.04	38.7	.5
Windsor	NS				23.4	1.7
Winnipeg	4	.07	.03	.05	NS	NS
Yellowknife	NS				38.8	.3
Network summary	80	0.08	0.01	0.04	28.2	0.9

NS, no sample

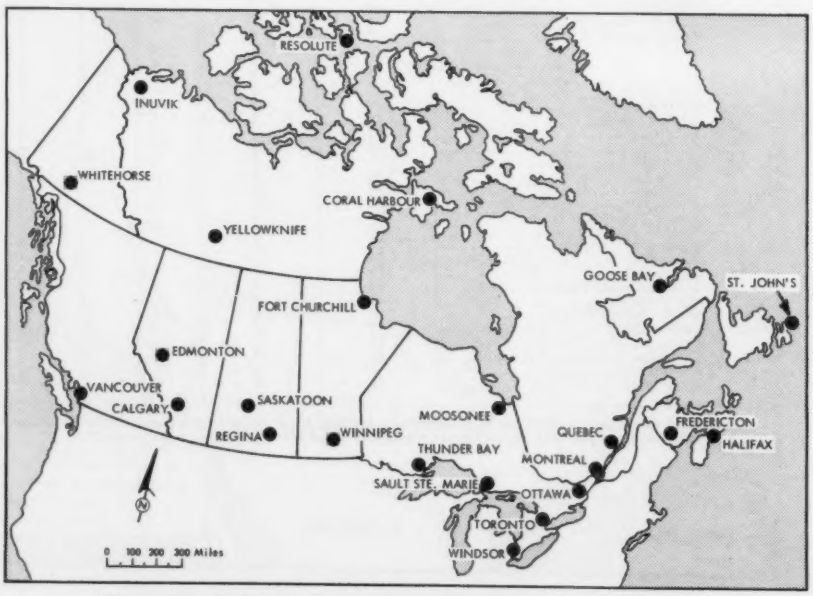

Figure 4. Canadian air and precipitation sampling stations

REFERENCES

(1) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(2) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(3) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(4) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(5) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

Figure 5. Pan American Air Sampling Program stations

4. Pan American Air Sampling Program February 1974

Pan American Health Organization and U.S. Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 5. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The February 1974 air monitoring results from the participating countries are given in table 4.

Table 4. Summary of gross beta radioactivity in Pan American surface air, February 1974

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average [a]
Argentina: Buenos Aires	0			
Bolivia: La Paz	0			
Chile: Santiago	0			
Colombia: Bogota	19	0.07	0.00	0.03
Ecuador: Cuenca	2	.01	.00	.01
Guayaquil	16	.04	.00	.02
Quito	12	.02	.00	.00
Guyana: Georgetown	0			
Jamaica: Kingston	0			
Peru: Lima	15	.03	.00	.01
Trinidad and Tobago: Port of Spain	0			
Venezuela: Caracas	13	.06	.00	.03
Pan American summary	77	0.07	0.00	0.02

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³

5. California Air Sampling Program February 1974

Radiologic Health Section
California Department of Health

The Radiologic Health Section of the California Department of Health with the assistance of several cooperating agencies and organizations operates a surveillance system for determining radioactivity in airborne particulates. The air sampling locations are shown in figure 6.

One of the objectives of the program is to evaluate the possibility that fixed effluent sources contribute to particulate activity in the air. Consequently, data from continuous air samplers placed in proximity to nuclear facilities are compared with those from similar equipment in nearby communities and at several "background" stations.[1]

Airborne particles are collected by a continuous sampling of air filtered through a 47

[1] Air samples near nuclear power reactors were obtained under contract number AT(49–1)–3549 between the U.S. Atomic Energy Commission and the California Department of Health.

Figure 6. California air sampling program stations

millimeter membrane filter, 0.8 micron pore size, using a Gast air pump of about 2 cubic feet per minute capacity, or 81.5 cubic meters per day. Air volumes are measured with a direct reading gas meter. Filters are replaced every 24 hours except on holidays and weekends.

All air samples are sent to the Sanitation and Radiation Laboratory of the State Department of Health. The filters are analyzed for gross alpha and beta radioactivity, 72 hours after the end of the collection period. The daily samples then are composited into a monthly sample for gamma spectroscopy and an analysis for strontium-89 and strontium-90. The monthly sample results are presented quarterly. Table 5 presents the gross beta radioactivity in air for February 1974.

Table 5. Gross beta radioactivity in California air February 1974

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Bakersfield	18	0.85	0.07	0.30
Barstow	28	.50	.10	.28
Berkeley	28	.32	.02	.15
Diablo Canyon Nuclear Power Plant	8	.24	.10	.19
El Centro	18	1.31	.00	.29
Eureka	18	.26	.06	.11
Fresno	17	.52	.09	.22
Humboldt Bay Power Plant: Unit 3	12	.12	.03	.08
Los Angeles	18	.40	.10	.23
Rancho Seco Nuclear Generating Station	12	.23	.00	.17
Redding	14	.35	.10	.20
Sacramento	19	.28	.00	.11
Salinas	18	.54	.05	.23
San Bernardino	13	.45	.12	.30
San Diego	17	.53	.13	.24
San Luis Obispo	18	.41	.03	.21
San Onofre Nuclear Generating Station	4	.30	.17	.25
Santa Rosa	3	.12	.04	.09
Summary	283	1.31	0.00	0.20

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors annual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual." [1]

A summary of the environmental radioactivity data follow for Brookhaven National Laboratory and Oak Ridge Area.

[1] Title 10, Code to Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Brookhaven National Laboratory[2] January–December 1971

Associated Universities, Inc.
Upton, N.Y.

Brookhaven National Laboratory is a scientific research center situated in Suffolk County on Long Island, about 70 miles east of New York City. Its location with regard to surrounding communities is shown in figure 1. Except for shoreline communities, much of the land area within 10 miles is currently either forested or under cultivation.

The laboratory site with its principal effluent-producing facilities is shown in figure 2. It consists of some 4500 acres, most of which is wooded, except for a central area of less than 1000 acres. The site terrain is gently rolling, with elevations varying 40 and 120 feet above

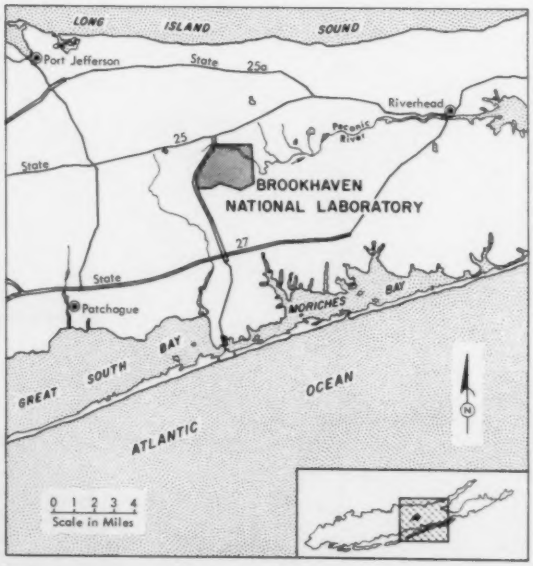

Figure 1. Central area of Suffolk County around Brookhaven National Laboratory

[2] Summarized from "Brookhaven National Laboratory, 1971 Environmental Monitoring Report, 1971," Associated Universities Inc., Upton, N.Y. 11973.

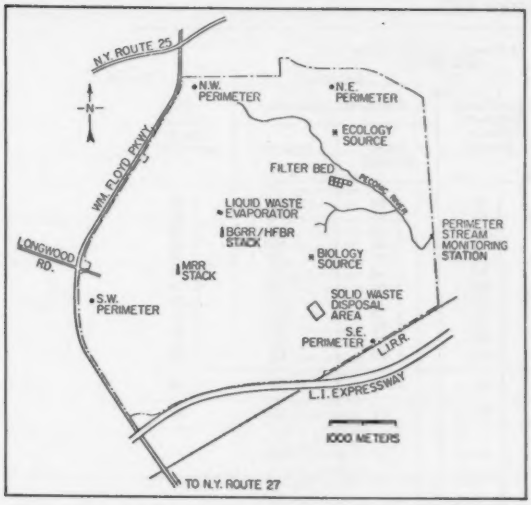

Figure 2. Effluent producing facilities, Brookhaven National Laboratory

sea level. The land lies on the west rim of the shallow Peconic River watershed, with the river itself rising in marshy areas in the north and east sections of the site.

A wide variety of scientific programs are conducted at Brookhaven, including research or development in the following areas:

1) structure and properties of matter;
2) physical, chemical and biological effects of radiation;
3) radioisotopes and other nuclear tools, and;
4) nuclear technology.

Among the major scientific facilities operated at Brookhaven to carry out the above programs are: the High Flux Beam Reactor (HFBR) is enriched uranium fueled, heavy water moderated and cooled, and has a routine power level of 40 MW; the Medical Research Reactor (MRR) is an integral part of the Medical Research Center, is enriched uranium fueled, natural water moderated and cooled, and is operated intermittently at power levels up to 3 MW; the Alternating Gradient Synchrotron (AGS) operates at energies up to 33 BeV; the 200 MeV Proton Linac serves as an injector for the AGS, but will also supply continuous currents of protons for isotope production by spallation reactions; the Tandem Van de Graaff, 60-inch Cyclotron, Research Van de Graaff, Vertical Accelerator and Chemistry Van de Graaff are used in medium energy investigation, as well as for special isotope production, and; the High Intensity Radiation Development Laboratory (HIRDL) contains million-curie range cobalt-60 and cesium-137 sources.

Additional programs involving irradiations and/or the use of radionuclides for scientific investigations are carried on at other laboratory facilities, including the Medical Research Center, the Biology Department (including two multicurie field irradiation sources), the Chemistry Department, and the Department of Applied Science. The latter includes the Hot Laboratory, where special purpose radioisotopes are developed and processed for on and offsite use.

Most of the airborne radioactive effluents at Brookhaven originate from the HFBR, the MRR, and the Research Van de Graaff. The first two also produce significant fractions of the laboratory's liquid radioactive effluents, but additional significant contributions originate from the Medical Research Center, the Hot Laboratory complex, as well as from decontamination and hot laundry operations.

External exposure monitoring

External radiation levels, including natural background (as influenced by fallout) and increments attributable to BNL activities were measured continuously at the four perimeter stations shown on figure 2. Included in each station's equipment was an ion chamber and dynamic condensor electrometer. Those units are capable of accurately measuring 10 μR/h and of detecting changes of the order of 1 μR/h.

The observed monthly average radiation levels are set forth in table 1. There was no increment to the natural background attributable to BNL activities, except at the northeast perimeter station. At this location, the Ecology Forest irradiation source, which contained about 7000 curies of cesium-137, produced a measurable radiation level. Since the station was located about 250 feet south of the present BNL north boundary, the observed readings have been adjusted on the basis of spot com-

Table 1. External radioactivity at BNL site perimeter including natural background January-December 1971

Month	Average exposure rates (mR/week) [a]					
	Northwest perimeter (background)	Southwest perimeter (background)	Southeast perimeter (background)	Northeast perimeter		All stations (background)
				(background)	(source)	
January	1.74	1.81	1.72	1.68	0.24	1.73
February	1.62	1.66	1.64	1.63	.25	1.64
March	1.64	1.67	1.67	1.59	.26	1.64
April	1.66	1.62	1.62	1.60	.26	1.63
May	1.74	1.73	1.83	1.61	.31	1.73
June	1.76	1.77	1.86	1.59	.32	1.74
July	1.77	1.79	1.85	1.63	.35	1.76
August	1.73	1.92	1.90	1.76	.38	1.83
September	1.72	1.90	1.90	1.72	.37	1.81
October	1.75	1.92	1.98	1.76	.35	1.85
November	1.80	1.97	2.06	1.82	.30	1.91
December	1.78	1.92	2.05	1.79	.28	1.89
Average	1.73	1.81	1.84	1.68	0.31	1.76
Yearly total	90	94	95	87	[b] 16	92
Radiation protection standards (*1*)	—	—	—	—	500	—

[a] Estimated error ±0.10 mR/wk.
[b] Measured 250 feet from north perimeter and adjusted on the basis of spot comparisons between levels at this location and the perimeter.

parisons, which indicate an average ratio of 0.2 between the station and the actual north perimeter radiation levels.

Ground-level air particulate, tritium, and radioiodine

During 1971, "high volume" (20 cubic feet per minute) positive displacement air pumps (Gast 3040) were operated at a monitoring station immediately east of the solid waste disposal area, and at the southeast and southwest perimeter monitoring stations (figure 2). The air sampling media consisted of a 3-inch diameter air particulate filter (Gelman Type G) followed by a 3 inch × 1 inch bed of petroleum-based charcoal (Columbia Grade LC 12/28 × mesh) for sampling of radiohalogens. The solid waste disposal area air particulate filter was changed and counted on a daily (5 times per week) basis. The remaining samples were changed and counted on a 2-week basis through September, and weekly thereafter.

After allowing several days for the decay of short-lived natural radioactivity, gross alpha counts of the 1-day air particulate samples (from the solid waste disposal area stations) were made using a 5-inch diameter ZnS coated photomultiplier. After a similar delay, gross beta counts were made of all air particulate samples, using a 5-inch beta scintillator. These data are shown in table 2. No consistent differences between sampling locations were apparent and there was no indication of BNL effluent radionuclides in air particulate samples at any location.

Continuous tritium vapor collections, using thermoelectric coolers, were made at the southeast and northeast perimeter stations which are most frequently downwind from the high flux beam reactor stack. These collections were composited on a monthly basis, and after enrichment by electrolysis, were assayed for tritium. Net concentrations of tritium vapor in air at the BNL perimeter, which are assumed to be principally attributable to HFBR stack effluent tritium vapor, were arrived at by subtracting the tritium concentrations in an offsite precipitation collection from the concentration found in the perimeter sample. The result was converted to an air concentration by assuming that 1 pCi/ml in vapor corresponds on the average to 10 pCi/cm^3 in air. This is only strictly so at

Table 2. Gross alpha and beta radioactivity in air particulate filters, BNL, January-December 1971

Month	Location	Number of samples	Concentration (fCi/m³)						
			Gross alpha			Number of samples	Gross beta		
			Maximum	Minimum	Average		Maximum	Minimum	Average
January	Waste disposal	15	2.9	0.5	0.7	21	116	45	75
	SW perimeter	—				2	112	80	96
	SE perimeter	—				—	—	—	—
February	Waste disposal	15	2.1	<1	1.2	20	153	21	87
	SW perimeter	—				2	102	59	81
	SE perimeter	—				2	142	83	112
March	Waste disposal	19	1.9	1	1.1	23	338	56	177
	SW perimeter	—				2	164	140	152
	SE perimeter	—				2	199	143	171
April	Waste disposal	17	2.2	<1	.9	22	395	43	230
	SW perimeter	—				2	214	212	213
	SE perimeter	—				2	255	255	255
May	Waste disposal	14	7.0	1	1.4	24	910	72	428
	SW perimeter	—				2	445	258	352
	SE perimeter	—				2	450	128	289
June	Waste disposal	17	3.3	1	1.2	22	760	82	458
	SW perimeter	—				2	406	386	396
	SE perimeter	—				2	472	393	432
July	Waste disposal	15	1.8	1	.9	23	660	128	420
	SW perimeter	—				2	461	281	371
	SE perimeter	—				2	544	342	443
August	Waste disposal	18	3.2	<1	1.1	23	905	74	263
	SW perimeter	—				2	245	222	234
	SE perimeter	—				2	287	239	263
September	Waste disposal	17	1.6	1	.8	23	195	68	118
	SW perimeter	—				3	143	80	123
	SE perimeter	—				3	148	72	120
October	Waste disposal	16	3.1	<1	.8	23	144	24	77
	SW perimeter	—				4	171	27	93
	SE perimeter	—				4	182	48	104
November	Waste disposal	21	2.1	4	.9	21	165	38	80
	SW perimeter	—				4	67	46	57
	SE perimeter	—				4	90	72	84
December	Waste disposal	22	1.8	5	.8	22	128	27	74
	SW perimeter	—				4	86	43	43
	SE perimeter	—				4	96	76	86
1971 summary	Waste disposal	206	7.0	<1	1.0	267	910	21	207
	SW perimeter	—				33	461	27	179
	SE perimeter	—				31	544	48	215
Estimated error (at 95 percent confidence level)			±0.1 fCi/m³ or ±25 percent				±10 percent		
Radiation protection standard (1)			[a] 100				[b] 10 000		

[a] For unidentified alpha emitters.
[b] For unidentified beta emitters.

59°F and 50 percent relative humidity. These air concentration data are shown in table 3.

In addition to the gross beta counts indicated above, analyses for gamma-emitting nuclides were performed on a consolidated monthly composite of all individual air particulate samples shortly after the end of each month. Additional air particulate analyses were also scheduled at 6-month and 1-year postcollection to facilitate the resolution of short- and long-lived nuclides with photopeaks too close to be resolved by the NaI detection system employed. The charcoal samples were reanalyzed at 1-month postcollection to determine iodine-131 by decay in its photopeak region during this time. Available data are reported in table 4. In the absence of any recent fission products during most of the year, all transactions in the energy region of iodine-131 have been attributed to 285-day cerium-144. These data do not disclose any indication of BNL effluents.

Precipitation

Two pot-type rain collectors, each with a surface area of 0.33 m², were situated adjacent to the BNL filter beds. Two routine collections were made from these, one whenever precipitation was observed during a previous 24-hour (or weekend) period, and the other, once a week whether or not precipitation had occurred.

Table 3. Tritium concentrations in air, BNL January-December 1971

Month	Number of samples	Southwest perimeter Concentration (pCi/m³)	Number of samples	Northeast perimeter Concentration (pCi/m³)
January	[a] 1	11	0	—
February	[a] 1	10	0	—
March	[a] 1	5	0	—
April	[a] 1	4	[a] 1	10
May	[a] 1	3	[a] 1	9
June	[a] 1	15	[a] 1	12
July	[a] 1	0	[a] 1	15
August	[a] 1	1	[a] 1	3
September	[a] 1	0	[a] 1	4
October	[a] 1	2	[a] 1	3
November	0	—	0	—
December	[a] 1	3	0	—
Average		5		8
Radiation protection standard (*1*)		200 000		200 000

[a] Tritium analysis made of monthly composite samples of water vapor. The net tritium concentration in this, arrived at by subtracting that in an offsite precipitation sample, is converted to air concentration on the assumption that on the average 1 pCi/m in vapor corresponds to 10 pCi/m³ in air which is strictly so at 59°F, and 50 percent relative humidity.
Estimated error (at 95-percent confidence limits): ±1 pCi/m³, or ±50 percent.

Part of each collection was evaporated for gross beta counting, a small fraction composited for monthly tritium analysis, and the balance put through ion exchange columns for subsequent monthly strontium-89, strontium-90 and gamma analyses. The data are reported in table 5.

With the exception of tritium, there is no indication in the onsite precipitation collection of the washout of BNL released airborne radioactivity. As indicated in table 6, the tritium concentration in the collector located at the filter beds (which are in a predominant downwind direction) appears to have been about twice that of the offsite collection. The total deposition of tritium on the BNL site (about 4000 acres) during 1971 was between 5–10 curies. The lower estimate is based on the concentration in the offsite collection, and the upper on that in the onsite downwind sample.

Liquid effluent monitoring

Within established administrative limits, microcurie amounts of low-level radioactive liquid effluents are routinely disposed of by release into the laboratory's sanitary waste system. This affords considerable dilution by a large volume ($\sim 10^6$ gal/day) of uncontaminated water. Primary treatment to remove suspended solids from the liquid effluents discharged to this system is provided by a 250 000 gallon clarifier. The liquid effluent then flows onto sand filter beds, from which most of it is recovered by an underlying tile field. It is then

Table 4. Gamma-emitting radionuclides in monthly air composites, BNL, January-December 1971

Month	Radionuclide concentration (fCi/m³)								
	Beryllium-7	Zinc-65	Zirconium-niobium 95	Ruthenium-106	Antimony-125	Iodine-131 [a]	Cesium-137	Barium-lanthanum-140	Cerium-144
January	94	1	12	7	1	<1	4	<1	22
February	103	3	19	7	3	<1	5	<1	28
March	243	3	70	18	3	<1	10	<1	77
April	374	3	142	13	4	<1	12	<1	118
May	476	7	227	43	7	<1	17	<1	188
June	498	10	274	51	8	<1	26	<1	235
July	435	9	192	39	8	<1	23	<1	202
August	222	7	104	33	5	1	17	<1	111
September	167	3	42	14	3	<1	17	<1	54
October	84	2	13	6	2	<1	3	<1	25
November	77	1	9	5	1	1	3	4	21
December	96	1	5	4	1	2	2	3	16
Average	231	4	[b] 24	20	3	<1	12	<1	91
Estimated percent error of individual sample	±25	±50	±25	±33	±33	±50	±25	±50	±25
Radiation protection standard	4×10^7	2×10^6	1×10^6	2×10^5	9×10^5	1×10^5	5×10^5	1×10^6	2×10^5

[a] Charcoal filter collection; all other nuclides collected on air particulate filter.
[b] Pending.

Table 5. Gross beta and radionuclide activity in precipitation, BNL January-December 1971

Month	Amount (inches)	Gross beta concentration (pCi/liter)	Gross beta deposition (nCi/m²)	Radionuclide deposition (nCi/m²)							
				^{7}Be	^{65}Zn	^{90}Sr	^{95}Zr-Nb	^{131}I	^{137}Cs	^{140}Ba-La	^{144}Ce
January	1.97	31	1.57	5.2	<0.1	0.04	0.4	0.1	0.1	0.1	1.8
February	4.62	42	2.34	14.4	<.1	.12	2.7	<.1	.2	<.1	1.2
March	2.37	81	4.95	9.6	<.1	.17	3.5	<.1	.2	<.1	1.4
April	1.70	122	4.59	4.6	<.1	.05	1.2	<.1	.2	<.1	1.3
May	3.12	169	14.03	26.6	.1	.30	7.6	<.1	1.0	<.1	3.0
June	.74	219	4.39	10.3	<.1	.27	3.4	<.1	.5	<.1	1.8
July	3.37	36	2.72								
August	5.57	19	2.53	6.7	<.1	.13	1.1	<.1	.2	<.1	1.5
September	1.98	9	.38	1.4	<.1	.05	.2	<.1	.1	<.1	.8
October	3.11	16	1.25	5.9	<.1	.14	.4	<.1	.1	<.1	1.2
November	3.45	39	4.75	1.7	<.1	.11	.1	<.1	<.1	<.1	.8
December	3.23	58	4.77	4.8	.1	.05	.4	.3	.1	.6	.6
Summary	35.23	[a] 56	48.27	91.2	<1.0	1.43	21.0	<1.0	2.8	<1.0	15.5
Average estimated error	0.25	±6	±2.39	±19.0	—	±0.14	±2.1	—	±0.8	—	±3.8
Radiation protection standard (1)[a]		3×10³									

[a] For release to uncontrolled areas of mixture of radionuclides containing <10 percent strontium-90, iodine 125-133, and long-lived natural alpha-emitting nuclides.

Table 6. Average tritium concentration in precipitation BNL, January-December 1971

Month	Onsite		Offsite
	Concentration (pCi/liter)	Deposition (nCi/m²)	Concentration (pCi/liter)
January	661	33	300
February	300	17	210
March	1 570	96	459
April	1 470	55	605
May	972	81	705
June	1 186	136	523
July			
August	460	61	306
September	325	41	82
October			
November	273	16	104
December	248	20	148
Total	[a] 650	556	[a] 320
Average estimated error	±65	±57	±32
Radiation protection standard (1)[b]	3×10⁴		3×10⁴

[a] Weighted average.
[b] For tritium in water released to the offsite environment.

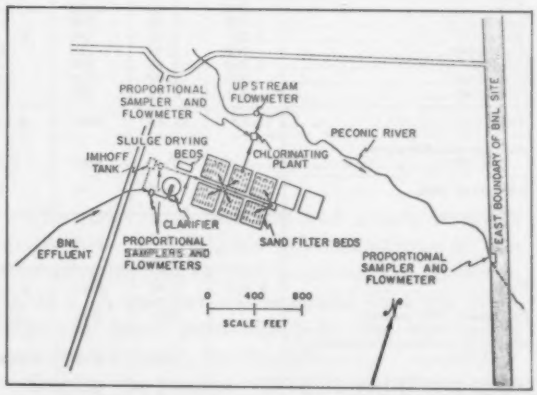

Figure 3. Sewage treatment plant, including related monitoring arrangements, Brookhaven National Laboratory

chlorinated and released into a small stream that forms one of the headwaters of the Peconic River.

A schematic illustration of the sewage treatment plant, including the related monitoring arrangements, are shown in figure 3. In addition to the inplant flow measurement and sampling instrumentation, totalizing flowmeters (Leopold and Stevens, TF 61–2), which include provision for actuating a sampler with each 2000 gallons of flow in combination with a positive-action, battery-operated sampler (Brailsford DU-1), are installed at the Chlorine House, at the former site boundary, 0.5 miles downstream on the Peconic and at the site boundary (1.6 miles downstream).

The monthly average flow and the monthly totals of gross beta and principal nuclide activities at the clarifier (input to the filter beds) and at the Chlorine House (output from the beds) are shown in table 7. Yearly totals and average concentrations are also indicated. It is

Table 7. Environmental monitoring liquid effluent flow, total activity and concentration of principal beta and gamma emitters at Clarifier and Chlorine House, BNL, January–December 1971

Month	Flow ($\times 10^6$ liters)	Gross beta *	^{3}H	^{7}Be	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr-Nb	^{131}I	^{137}Cs	^{144}Ce
		Clarifier (mCi)									
January	1.142	1.62	1122	<0.10	0.13	0.07	0.19	<0.01	0.18	0.40	0.34
February	.919	3.05	588	.40	.14	<.01	.15	<.01	2.04	.35	.30
March	.933	1.35	489	.24	.07	<.01	.12	.02	1.01	.19	.30
April	.924	2.54	532	.22	.09	.05	.12	.04	1.62	.26	.57
May	1.477	3.24	1333	<.10	.11	<.01	.27	.62	.72	.66	.40
June	1.209	1.60	4291	.26	.05	<.01	.21	.04	.87	.22	.26
July	1.304	2.51	626	.51	.09	<.01	.20	<.10	.58	.30	.40
August	1.701	13.48	704	<.10	.26	<.01	6.36	<.10	2.63	5.11	1.72
September	1.339	5.77	407	.56	.09	<.01	2.77	<.10	1.17	1.15	.64
October	1.627	3.34	564	.29	.06	<.01	1.09	<.10	.66	.53	.43
November	1.003	1.55	148	.13	<.05	<.01	.46	<.10	.10	.41	.17
December	1.001	3.98	158	.28	.04	.02	.38	<.10	.70	.38	.91
Total	14.579	44.03	10 962	3.04	1.16	0.19	12.32	1.03	12.28	9.96	6.44
Average concentration (pCi/liter)		30.2	7 510	2.0	0.8	0.1	8.5	0.7	8.4	6.8	4.4
Percent of total		100	—	7	3	<1	28	2	28	23	14
		Chlorine House (mCi)									
January	0.870	1.15	1150	<0.10	0.02	<0.01	0.10	<0.01	0.07	0.90	0.22
February	.697	1.67	466	.35	.01	<.01	.10	<.01	.39	.78	.23
March	.784	1.23	432	.18	.03	<.01	.11	<.01	.23	.68	.34
April	.760	1.34	439	.12	.02	<.01	.13	<.01	.16	.49	.18
May	1.167	1.72	1207	<.10	.02	.03	.19	.04	.09	.48	.11
June	.963	1.24	3454	<.10	.03	<.01	.15	.03	.12	.55	.15
July	1.020	1.60	598	.24	.02	<.01	.12	—	.13	.50	.24
August	1.347	1.36	546	<.10	.02	<.01	.31	<.10	.19	.51	.29
September	.552	1.04	108	.24	.01	<.01	.77	.01	.26	.27	.17
October	1.293	5.50	463	.43	.02	<.01	5.18	—	.28	.97	.36
November	.905	2.90	131	.15	.01	.01	1.33	—	<.10	.76	.40
December	.871	3.79	122	.30	.09	.02	1.18	—	.46	.69	.49
Total	11.23	24.54	9116	2.21	0.30	0.10	9.67	0.015	2.44	7.58	3.18
Average concentration (pCi/liter)		21.0	8120	2.0	0.3	0.1	8.6	0.1	2.2	6.8	2.8
Percent of total		100	—	9	1	<1	39	1	10	31	13
		Ground water (mCi)									
Total	3.360	7.36	2730	0.67	.010	0.03	2.90	0.03	0.74	2.28	0.94
Estimated error percent		±10	±10	±25	±50	±50	±10	±50	±25	±10	±25
Radiation protection standard (1) (pCi/liter)		600	3×10^6	2×10^4	5×10^4	1×10^5	300	6×10^4	300	2×10^4	1×10^4

* Includes only gamma emitters; does not include tritium.

apparent that not all of the liquid effluent flow into the sand filter beds appears in the output from them. The balance presumably mixes with the ground water flow under the beds. Estimates of the amounts of radioactivity released to the ground water in this fashion during 1971 are also shown in table 7. These were calculated on the assumption that the average concentrations of the contained nuclides corresponded to those in the observed output from the beds.

Flow, activity, and concentration information at the former site boundary and at the present site boundary are shown in table 8. Upper limit estimates of the total activity so released to ground water, based on the concentrations observed at the boundary, are also shown in table 8.

Monthly "grab" water samples were obtained at, on and offsite locations along the upper tributary of the Peconic River, into which the laboratory routinely discharges low-level radioactive wastes. Reference "grab" samples were also obtained from other nearby streams and bodies of water outside the laboratory's drainage area. The sampling locations as shown in figure 3 were as follows:

Table 8. Liquid effluent flow, total activity and concentration of principal beta and gamma emitters at site boundary BNL (1.6 miles downstream), 1971

Month	Flow ($\times 10^6$ liters)	Concentration (mCi)									
		Gross beta [a]	^{3}H	^{7}Be	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr-Nb	^{131}I	^{137}Cs	^{144}Ce
January	0.627	0.72	716	<0.10	0.01	0.01	0.06	<0.10	0.03	0.50	0.21
February	.494	.85	270	.25	<.01	<.01	.06	.03	.21	.31	.12
March	.813	1.35	362	.39	.02	<.01	.13	.05	.13	.50	.21
April	.728	1.37	367	.23	.01	<.01	.12	.04	.08	.36	.18
May	.697	1.57	521	.43	.01	.01	.17	.08	.13	.31	.10
June	.263	.30	746	<.10	.01	<.01	.06	.01	.02	.11	.06
July	.064	.09	37	.01	<.01	<.01	.01	<.01	.01	.03	.02
August	.061	.07	27	<.01	<.01	<.01	.01	—	.01	.03	.01
September	.053	.09	15	.02	<.01	<.01	.08	<.01	.02	.02	.01
October	.067	.21	21	.03	<.01	<.01	.26	—	.01	.04	.03
November	.067	.26	10	.03	<.01	<.01	.11	—	<.01	.03	.02
December	.067	.34	9	.04	<.01	<.01	.08	—	.01	.03	.03
Total	4.001	7.22	3101	1.54	0.10	0.07	1.15	0.27	0.67	2.27	1.00
Average concentration (pCi/liter)		18.0	7800	3.9	0.2	0.1	3.1	0.6	1.7	5.7	2.5
Percent of total		100	—	21	1	1	17	3	9	31	14
		Ground water (mCi)									
Total	8.094	14.59	6 075	3.15	0.16	0.08	2.52	0.49	1.37	4.61	2.02
Estimated error (percent)		±10	±10	±25	±50	±50	±10	±50	±25	±10	±25
Radiation protection standard (1) (pCi/liter)		1000	3×10^5	2×10^5	5×10^4	1×10^5	300	6×10^4	300	2×10^4	1×10^4

[a] Includes only gamma emitters; does not include tritium.

Offsite (Peconic River, downstream)

A—Peconic River at Schultz Road, 15 900 feet

B—Peconic River at Wading River-Manorville Road, 23 100 feet

C—Peconic River at Manorville, 35 000 feet

D—Peconic River at Calverton, 46 700 feet

R—Peconic River at Riverhead, 63 500 feet

Controls (not in BNL drainage)

E—Peconic River, upstream from BNL effluent outfall

F—Peconic River, north tributary (independent of BNL drainage)

H—Carman's River—outfall of Yaphank Lake

I—Artist Lake (maintained by water table, no surface outfall)

J—Lake Panamoka (maintained by water table, no surface outfall)

The individual monthly and yearly average gross beta and tritium concentrations at the downstream and control locations are shown in table 9. A comparison suggests that the BNL effluents have little effect on the prevailing concentrations in the Peconic.

During the summer of 1971, additional sampling of the stream bottom sediment, of immersed and emergent vegetation, and of small stream fauna was conducted along the length of the Peconic. Control samples were obtained from the Carman's River. Sampling locations correspond to those used for monthly water samples. In addition, samples were obtained onsite at the following locations:

Onsite (downstream)

K—Peconic River at effluent outfall

L—Peconic River, 1300 feet below effluent outfall

L'—Peconic River, 2000 feet below effluent outfall

Table 9. Gross beta (and tritium) in downstream and control water samples, January-December 1971

Month	Gross beta concentrations (pCi/liter)									
	Downstream locations					Control locations				
	A	B	C	D	R	E	F	H	I	J
January	5	3	4	3	—	3	3	1	15	6
February	6	4	3	4	—	3	3	1	4	4
March	7	4	4	4	—	4	2	3	5	5
April	6	4	5	4	6	5	4	3	7	5
May	28	6	10	15	9	7	17	7	12	8
June	6	4	5	4	8	7	4	3	6	6
July	3	3	4	4	6	16	4	2	6	3
August	3	2	4	3	6	8	3	2	6	3
September	4	3	3	2	3	8	4	2	3	3
October	2	3	2	3	4	7	3	2	3	2
November	<1	1	5	2	4	7	5	<1	5	2
December	10	9	9	9	—	7	12	6	11	7
Average	7	4	5	5	[c] 6	7	5	3	7	5
	Tritium (nCi/liter)									
January	4	3	<1	<1	—	<1	<1	<1	<1	<1
February	<1	<1	<1	<1	—	3	<1	<1	<1	<1
March	<1	1	<1	<1	—	<1	<1	<1	<1	<1
April	<1	3	<1	<1	<1	<1	<1	<1	1	<1
May	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
June	6	4	<1	<1	<1	<1	<1	<1	<1	<1
July	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
August	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
September	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
October	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
November	<1	<1	<1	<1	<1	1	<1	<1	<1	<1
December	<1	<1	<1	<1	—	<1	<1	<1	<1	<1
Average	1	1	<1	<1	[c] <1	<1	<1	<1	<1	<1

[a] Radiation protection standard (1) for gross beta, 1000 pCi/liter.
[b] Radiation protection standard for tritium, 3 000 nCi/liter.
[c] Partial year.

Table 10. Gamma emitting radionuclides in Peconic River and Carman's River sediment, BNL, January-December 1971

Peconic River station	Concentration (pCi/kg)					Potassium [a] (g/kg)
	Cobalt-60	Zinc-65	Cesium-137	Thorium	Uranium	
O [b]	93	95	409	737	484	3.17
K	NA	NA	846	1300	NA	1.19
L	190	41	1230	1330	1060	4.17
L'	1030	150	3330	1650	NA	3.91
M	172	63	1590	4890	NA	3.68
Q	NA	NA	718	645	642	2.02
A	31	47	1170	669	522	1.61
B	44	81	NA	841	839	3.93
C	NA	NA	727	925	646	3.12
D	26	7	277	357	524	1.74
V	66	32	228	369	527	2.63
W	31	6	84	407	436	2.13
R	NA	NA	88	290	116	0.88
Y	NA	64	NA	509	NA	2.44
Reference (Carman's River):						
Average (2 samples)	NA	NA	187	607	427	2.69

[a] Determined from potassium-40.
[b] Sewage outlet.
NA, no analysis.

M—Peconic River, 2600 feet below effluent outfall (at former BNL boundary)

Q—Peconic River, 6900 feet downstream (at BNL boundary).

Offsite

V—Peconic River (54 000 feet downstream)

W—Peconic River (59 600 feet downstream)

The sediment data are shown in table 10. Small concentrations of cobalt-60 and zinc-65 as well as small increments in the cesium-137, uranium, and thorium backgrounds are apparent in most samples obtained onsite and in the upper reaches of the Peconic. The corresponding vegetation data are shown in table 11. These show considerable scatter. Small concentrations of cobalt-60 and a slight excess of cesium-137 over prevailing backgrounds may have been present in vegetation in the upper reaches of the Peconic, at the BNL boundary and immediately downstream. A few samples of fish, turtles, and one of the clams were also obtained along the upper reaches of the Peconic. These data, which are shown in table 12, appear compatible to those found in vegetation. When the concentrations found in these samples are compared with radiation concentration guides, calculated on the basis of an assumed intake of 50 grams/day, the potential exposures from aquatic animals obtained from the upper reaches of the Peconic appear to be quite insignificant.

Potable water supply wells

The laboratory's potable water supply wells and cooling water supply wells are about 100 feet deep, or about 50 feet below the water table in the Long Island surface layer of glacial outwash, sand and gravel. As apparent from figure 4, most of these wells are located generally west to northwest, and therefore upstream in the local ground water flow pattern (*2*) of the laboratory's principal facilities. The exceptions are main well numbers 1 and 3, and the

Table 11. Concentrations of gamma-emitting nuclides in Peconic River and Carman's River vegetation, BNL January-December 1971

Station and type of sample	Concentration (pCi/kg)						Potassium * (g/kg)
	Beryllium-7	Cobalt-60	Zirconium-niobium-95	Cesium-137	Thorium	Uranium	
Carex: (sedge)							
K	1450	NA	861	1370	284	160	1.84
L	NA	NA	1050	1440	378	NA	NA
L	1920	NA	1164	1100	278	283	1.00
M	1680	NA	686	514	173	204	NA
Q	2340	NA	488	2990	252	349	.13
A	NA	NA	666	5050	NA	388	.64
B	1580	NA	740	1420	251	189	1.11
C	895	NA	551	1130	138	94	NA
D	NA	NA	NA	NA	NA	NA	NA
V	3230	NA	1330	1800	396	194	6.70
W	NA	811	1030	381	1500	NA	3.05
Y	1130	NA	750	415	958	836	4.20
Potedaria: (pickerel weed)							
C	265	NA	924	NA	39	496	1.27
D	238	NA	71	100	62	41	1.10
V	645	NA	222	NA	63	52	1.96
W	451	NA	116	106	67	63	.69
R	43	NA	96	NA	26	44	1.47
Y	109	NA	186	NA	36	28	.88
Vallisneria: (wild celery)							
M	NA	249	NA	380	208	NA	.62
C	289	NA	126	68	79	NA	1.28
D	217	30	88	57	53	58	.91
Reference vegetation: (Carman's River)							
Carex	273	NA	696	223	74	67	4.70
Miscellaneous	668	NA	315	272	124	93	5.61

* Potassium determined from potassium-40.
NA, no analysis.

Table 12. Environmental monitoring, concentrations of gamma-emitting nuclides in animals obtained from the Peconic River, BNL, 1971

Station and type of sample	Number of samples	Concentration (pCi/kg)					Potassium [a] (g/kg)
		Beryllium-7	Cobalt-60	Cesium-137	Thorium	Uranium	
Snapping turtle:	2						
L		220	NA	478	NA	82	0.52
M		7176	NA	1270	1586	1372	4.82
Box turtle:	1						
L		NA	NA	13 520	2500	NA	NA
Eastern painted turtle:	4						
M		348	NA	1290	422	173	NA
M		NA	NA	672	144	161	1.18
M		7860	NA	889	215	130	NA
C		190	NA	205	NA	58	1.62
Pickerel:	5						
M		NA	NA	795	352	864	NA
M		1120	NA	805	NA	416	NA
Q		NA	NA	1480	263	169	NA
A		NA	445	247	109	170	NA
A		815	NA	464	401	204	NA
Catfish:	3						
Q		1000	NA	605	443	486	NA
B		335	NA	580	164	129	NA
C		454	NA	654	205	184	1.78
Perch:	2						
Q		NA	NA	647	201	218	NA
Q		689	NA	1280	793	869	NA
Clams: (several counted together)	1						
C		129	NA	89	210	228	.31
Radiation Protection Standard [b]		9×10^7	2×10^6	9×10^6	9×10^4	9×10^5	NA

[a] Determined from potassium-40.
[b] Assumed intake of 50 g/day.
NA, no analysis.

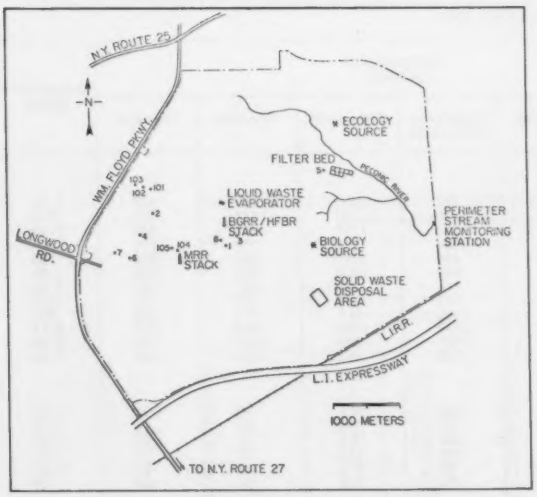

Figure 4. Brookhaven National Laboratory, potable and cooling water supply wells

small well number 5 adjacent to the sand filter beds. A total of about 5×10^6 gal/day is obtained from these wells.

Monthly grab samples were scheduled for these wells. These were analyzed for gross alpha, gross beta, and tritium. All gross alpha concentrations were less than 1 pCi/liter, and all tritium concentrations were less than 1 nCi/liter. The gross beta results are set forth in table 13. There are no differences in the gross beta concentrations in these wells which might be attributed to BNL effluents.

Recharge basins

About 4×10^6 gal/day of the total water pumped from the ground water supply under the BNL site is returned to this supply in three large open recharge sumps located about 1 km north of the Liquid Waste Evaporatory Facility, about 1 km east of the HFBR, and about 1 km south of the MRR. These are monitored by routine monthly grab sampling. Their average gross beta and tritium concentrations were only very slightly in excess of those in the BNL supply wells.

Table 13. Gross beta and tritium [a] concentrations in potable water supply wells, BNL, January-December 1971

Well number	Concentration (pCi/liter)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Average
1	1.0	1.0	2.6	2.1	3.5	1.4	NS	NS	NS	<1.0	<1.0	0.9	1.5
2	<1.0	<1.0	4.2	2.4	4.1	1.8	NS	NS	NS	<1.0	<1.0	2.6	1.9
3	<1.0	<1.0	1.3	2.3	2.8	2.9	NS	NS	NS	<1.0	<1.0	1.6	1.4
4	1.2	1.6	2.9	3.2	2.7	1.2	NS	NS	NS	NA	2.2	2.2	2.2
5	<1.0	<1.0	3.1	2.8	3.1	1.4	NS	NS	NS	1.2	<1.0	1.7	1.7
6	1.2	1.4	5.5	2.2	4.0	1.4	NS	NS	NS	1.3	2.8	4.7	2.8
7	<1.0	<1.0	1.5	2.7	2.7	1.1	NS	NS	NS	<1.0	2.2	1.5	1.5
101	1.0	<1.0	1.6	1.5	NA	1.2	NS	NS	NS	<1.0	1.5	.9	1.0
102	<1.0	<1.0	4.0	1.6	NA	NS	NS	NS	NS	<1.0	1.4	1.3	1.4
103	1.6	2.1	1.5	2.2	NA	NS	NS	NS	NS	1.3	1.9	2.4	1.9
104	<1.0	NA	NA	2.3	2.8	1.6	NS	NS	NS	<1.0	<1.0	<1.0	1.2
105	2.1	NA	NA	1.9	2.9	1.6	NS	NS	NS	2.1	<1.0	<1.0	1.7

Radiation protection standard (*1*): 100 pCi/liter (for unidentified nuclides, in the absence of radium-226 or radium-228).

[a] All tritium concentrations <1.0 nCi/liter.
NS, no sample.
NA, no analysis.

Ground water surveillance

Several areas from which there is a potential for the migration of radioactivity downward from the surface into the saturated zone of ground water, have been identified. Ground water sampling was routinely conducted in shallow wells located adjacent to and downstream from these areas. These areas include the sand filter beds and downstream along the Peconic River, the solid waste disposal area, the former open-pit dump and the sanitary landfill which replaced it in 1967, and the decontamination facility sump. Their locations and those of the related ground water surveillance wells are shown in figure 5.

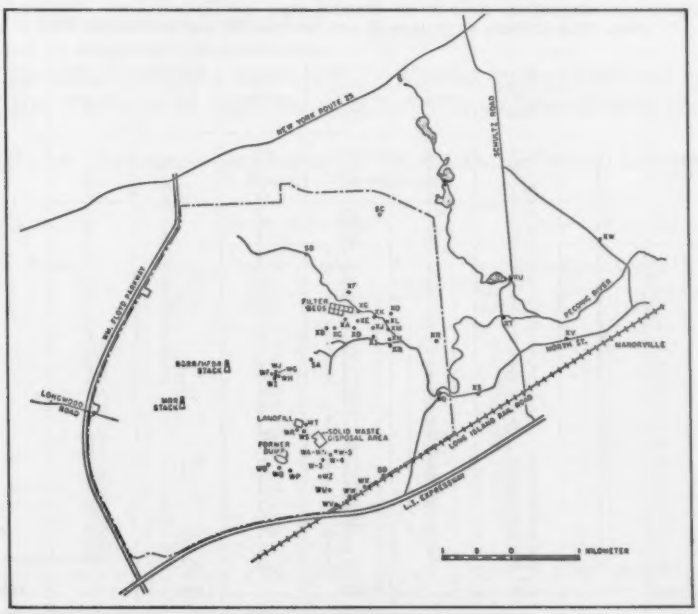

Figure 5. Ground water surveillance wells Brookhaven National Laboratory

Table 14. Radioactivity in sand filter beds and Peconic River area ground water surveillance wells BNL, January-December 1971

Well	Number of samples	Gross alpha (pCi/liter)	Number of samples	Gross beta (pCi/liter)	Number of samples	Tritium (nCi/liter)	Number of samples	Strontium-90 (pCi/liter)	Number of samples	Cesium-137 (pCi/liter)
SA	13	1.0	13	5.9	12	<1.0	2	0.2	2	<0.5
SB	11	<.5	11	1.8	10	<1.0	2	.2	2	<.5
SC	8	<.5	8	2.8	8	<1.0	NS	—	NS	—
SD	13	<.5	13	1.5	13	<1.0	NS	—	NS	—
XA	12	<.5	13	10.6	13	6.9	1	5.0	1	<.5
XB	4	1.2	4	7.5	2	.5	1	.2	1	<.5
XC	7	1.3	8	8.4	2	.5	1	3.2	1	<.5
XD	12	<.5	12	1.1	2	.4	1	<.2	1	<.5
XE	12	.7	12	2.5	12	11.0	1	.2	1	<.5
XF	7	<.5	7	2.0	1	.2	NS	—	NS	—
XG	7	<.5	7	6.0	7	4.8	1	3.1	1	.6
XH	11	<.5	11	1.7	2	.6	1	.5	1	<.5
XI	7	<.5	7	1.7	2	.2	1	.4	1	<.5
XJ	7	<.5	7	3.1	3	.3	1	1.8	1	<.5
XK	7	<.5	7	10.8	7	7.7	1	2.1	1	<.5
XL	13	1.1	13	19.9	13	10.5	1	13.0	1	<.5
XM	13	<.5	13	9.0	13	5.7	1	5.0	1	1.2
XN	7	2.2	7	6.8	3	.4	1	.8	1	<.5
XO	7	.9	7	7.1	3	.2	1	2.3	1	<.5
XQ	12	<.5	12	4.8	12	8.6	NS	—	NS	—
XR	2	.7	2	5.6	2	<1.0	NS	—	NS	—
XS	12	1.0	12	7.1	2	.3	NS	—	NS	—
XT	13	<.5	13	2.4	2	.4	NS	—	NS	—
XU	13	<.5	13	2.3	1	.4	NS	—	NS	—
XV	13	<.5	13	36.3	2	.6	NS	—	NS	—
XW	13	<.5	13	3.2	2	.6	NS	—	NS	—
Radiation protection standard (*1*)		[a] 100		[b] 300		300		300		2×10^4

[a] If iodine-129, radium-226 and radium-220 not present.
[b] If iodine, 125,-133, strontium-90, and alpha-emitters not present.
NS, no sample.

Table 15. 1971 environmental monitoring, solid waste disposal area, landfill and dump area, and 650 sump, gross alpha gross beta, tritium, strontium-90 and cesium-137 concentrations, BNL

Well	Number of samples	Gross alpha (pCi/liter)	Number of samples	Gross beta (pCi/liter)	Number of samples	Tritium (nCi/liter)	Number of samples	Strontium-90 (pCi/liter)	Number of samples	Cesium-137 (pCi/liter)
WA	6	2.7	8	69 800	NS	—	1	326	6	68 300
WB	11	<.5	11	64	2	0.70	1	31	1	0.9
WC	12	<.5	11	17	2	.68	NS	—	NS	—
WD	12	<.5	12	19	13	3.3	NS	—	NS	—
WE	11	<.5	11	24	1	.7	1	11	1	<.5
WF	7	<.5	7	427	1	.6	1	453	1	1.4
WG	9	<.5	9	26	1	.5	1	7	1	<.5
WH	7	<.5	7	7.5	1	.5	1	3	1	2
WI	2	<.5	2	2.3	1	.4	1	4	1	.5
WJ	2	<.5	2	18	1	.5	1	7	1	<.5
WK	9	<.5	9	19	9	1.0	1	10	1	<.5
WL	9	<.5	9	130	9	.8	1	99	1	<.5
WM	9	<.5	9	8.9	9	7.8	1	.4	1	<.5
WN	10	<.5	10	3.1	3	.7	1	.2	1	<.5
WO	5	<.5	5	<1.5	1	.4	NS	—	NS	—
WP	6	<.5	6	4.0	6	2.6	NS	—	NS	—
WQ	7	<.5	7	5.3	7	2.5	NS	—	NS	—
WR	2	3.5	2	42	2	23	NS	—	NS	—
WS	6	<.5	6	1.7	2	.8	NS	—	NS	—
WT	8	<.5	8	1.6	2	.4	1	<.2	1	<.5
WU	NS		NS		NS		NS		NS	
WV	NS		NS		NS		NS		NS	
WW	2	<.5	2	3.4	2	<1.0	NS	—	NS	—
WX	2	<.5	2	3.4	2	<1.0	NS	—	NS	—
WZ	10	<.5	10	2.9	1	.6	NS	—	NS	—
W-1	1	<.5	1	93	1	.5	NS	—	NS	—
W-2	1	<.5	1	103	1	.8	NS	—	NS	—
W-3	1	<.5	1	3.9	1	<1.0	NS	—	NS	—
W-4	1	<.5	1	4.6	1	<1.0	NS	—	NS	—
W-5	1	<.5	1	1.1	1	<1.0	NS	—	NS	—
Radiation protection standard (*1*)		[a] 100		[b] 300		300		300		2×10^4

[a] If iodine-129, radium-226, and radium-220 not present.
[b] If iodine-125,-133, strontium-90, and alpha-emitters not present.
NS, no sample.

For convenience in assessing the data, the wells have been divided into several groups. Yearly average gross alpha, gross beta, and tritium concentrations of the wells generally in the proximity of the sand filter beds and downstream on the Peconic River are summarized in table 14. At least one sample from most of these locations was also analyzed for strontium-90 and cesium-137 (by gamma analysis) during the year. Corresponding information for the wells generally in the proximity or downstream of the solid waste disposal area, the landfill and dump zones, and of the decontamination facility sump (about 1 km east of the HFBR) is summarized in table 15.

From these data, it appears that the spread of contamination in the ground water, if any, is limited to within a few hundred feet of the identified foci and that this is limited to a small percentage of the applicable Radiation Protection Standards.

Milk sampling

Monthly samples of milk were obtained from the two nearest dairy farms located 10 km south-southwest and 10 km south-southeast of Brookhaven. These samples were analyzed for gamma-emitters and then processed through an ion exchange column to improve the lower detection capability for iodine-131. The data are indicated in table 16. There is no significant difference between these and the average 1971 concentrations reported (*3*) for milk samples in the northeast region of the United States by the Environmental Protection Agency.

Grass and soil sampling

Two sets of samples, one early in the growing season and one toward its end, were collected adjacent to most of the BNL perimeter monitoring stations and from a number of offsite farms. A few onsite samples were also obtained. These were analyzed for gamma-emitting nuclides. Soil samples are primarily intended to reflect surface deposition and are therefore obtained to a depth of approximately 2.5 cm (1 inch) in an open area or after removal of root material. The data for soil are shown in table 17 and those for grass in table 18. Comparison of offsite downwind samples (6 km northeast and 10 km southeast) with other samples discloses no consistent differences. Comparison of offsite samples with onsite samples suggests the possible presence of a slight excess of cesium-137 in samples obtained at the northeast perimeter and adjacent to the solid waste disposal area.

Summary

Natural background and radiation levels in the vicinity of Brookhaven National Laboratory

Table 16. Radionuclide concentrations in milk, Brookhaven National Laboratory January-December 1971

Month	Farm B (10 km SSW)				Farm C (10 km SE)			
	Strontium-90 [a] (pCi/liter)	Iodine-131 (pCi/liter)	Cesium-137 (pCi/liter)	Potassium [b] (g/liter)	Strontium-90 [a] (pCi/liter)	Iodine-131 (pCi/liter)	Cesium-137 (pCi/liter)	Potassium [b] (g/liter)
January		<5	16	1.42	NA	<5	18	1.33
February		<5	22	1.41	NA	<5	24	1.48
March	5	<5	24	1.41	10	<5	14	1.16
April		<5	12	1.35	NA	<5	10	1.21
May		<5	23	1.47	NA	<5	20	1.15
June	6	<5	27	1.44	5	<5	20	1.35
July		<5	16	1.32	NA	<5	15	1.21
August		<5	23	1.61	NA	<5	22	1.29
September	6	<5	20	1.00	11	<5	20	1.93
October		<5	15	1.34	NA	<5	22	1.49
November		<5	15	1.15	NA	<5	14	1.41
December	<3	<5	13	1.50	10	<5	11	1.25
Average	5	<5	19	1.37	9	<5	18	1.32
Radiation protection standard (*1*)	[c] 200	[c] 100	4×10^4	—	[c] 200	100	4×10^4	—

[a] Quarterly data of New York State Health Department (*4*).
[b] Potassium determined from potassium-40. Potassium in g/liter.
[c] Based on FRC Radiation Protection Guide (*5*) and an assumed intake of 1 liter/day.
NA, no analysis.

Table 17. Concentration of gamma-emitting nuclides in soil, BNL, January-December 1971

Location	Sampling month	Concentration (pCi/kg)					Potassium * (g/kg)
		Zirconium-niobium-95	Cesium-137	Cerium-144	Uranium	Thorium	
Offsite:							
Farm A, 3 km NW	June	810	4250	4710	1260	2460	7.90
	Sept	232	484	4490	1630	1760	11.50
Farm B, 10 km SSW	June	580	<500	2080	710	527	5.75
	Sept	311	521	2820	833	930	7.09
Farm C, 10 km SE	June	525	2060	2670	955	634	4.40
	Sept	184	1560	2340	865	950	4.35
Farm D, 15 km NW	June	453	1800	4320	1115	1255	9.70
	Sept	240	1760	4360	1800	2110	11.50
Farm H, 6 km NE	June	505	735	1735	730	550	5.14
	Sept	314	820	2220	582	650	4.85
Onsite:							
Northwest perimeter	June	191	443	<1000	975	1050	7.70
	Aug	304	413	2260	1295	1760	8.10
Southwest perimeter	June	335	2220	<1000	961	1410	7.81
	Aug	268	515	2390	1570	1590	10.00
Southeast perimeter	June	587	1350	<1000	712	1155	9.90
	Aug	1020	725	3060	1070	1380	9.01
Northeast perimeter	June	510	4700	<1000	3470	3880	17.30
	Aug	396	3140	3620	2470	2660	14.00
Solid waste disposal area	Sept	—	3620	NA	1290	1750	8.27
SW ecology forest	Sept	297	546	1630	707	808	5.07
Estimated error (percent)		±25	±25	±25	±25	±25	±25

* Potassium determined from potassium-40.
NA, no analysis.

Table 18. Concentration of gamma-emitting nuclides in grass, BNL, January-December 1971

Location	Sampling month	Concentration (pCi/kg)							Potassium * (g/kg)
		Beryllium-7	Zinc-65	Zirconium-niobiun-95	Cesium-137	Cerium-144	Uranium	Thorium	
Offsite:									
Farm A, 3 km NW	June	970	68	391	195	425	NA	NA	4.10
	Sept	1470	96	306	107	1075	177	324	6.10
Farm B, 10 km SSW	June	985	61	440	69	535	NA	NA	4.28
	Sept	732	95	111	75	471	<100	131	5.68
Farm C, 10 km SSE	June	705	75	316	196	<500	NA	NA	4.55
	Sept	1590	121	303	199	1020	<100	258	5.07
Farm D, 15 km NW	June	823	89	440	118	559	NA	NA	5.22
	Sept	580	104	132	125	715	199	230	5.25
Farm H, 6 km NE	June	1620	95	825	218	1190	NA	NA	5.30
	Sept	1760	79	442	145	1170	<100	<100	5.22
Onsite:									
Northwest perimeter	June	NS	NS	NS	NS	NS	NS	NS	NS
	Aug	2430	130	1020	289	2460	NA	NA	3.92
Southwest perimeter	June	1560	<50	795	204	438	NA	NA	4.41
	Aug	1160	119	352	87	759	NA	NA	5.55
Southeast perimeter	June	NS	NS	NS	NS	NS	NS	NS	NS
	Aug	1035	106	410	177	292	NA	NA	4.70
Northeast perimeter	June	2070	133	1115	233	1680	NA	NA	6.00
	Aug	1720	88	727	381	1260	NA	NA	3.94
Solid waste disposal area	Sept	1650	111	306	403	396	NA	NA	6.96
SW ecology forest	Sept	2260	96	426	220	469	NA	NA	3.92
Estimated error (percent)		±25	±50	±25	±25	±25			±25

* Potassium determined from potassium-40.
NA, no analysis.
NS, no sample.

attributable to its operations during 1971 are summarized in this report. Among the data reported are external radiation levels, air particulate, tritium, and radioiodine concentrations, precipitation, liquid effluent-related concentrations in stream, ground water and surveillance wells, milk, grass, and soil samples.

External radiation levels at the north boun-

dary of the laboratory, attributable to an ecology forest irradiation source, were 16 mR/year, or 3 percent of the applicable radiation protection standard (*1*). Other than tritium, there was no indication of BNL effluents in environmental air and precipitation samples. In air, the largest BNL effluent-related tritium concentration was 8 pCi/m^3, which is 0.004 percent of the AEC standard. In precipitation, it was 300 nCi/liter, which is 0.01 percent of the drinking water standard.

About 75 percent of the volume of liquid effluent released onto the sand filter beds at the BNL sewage treatment plant is recovered and flows into the headwaters of the Peconic River, while about 25 percent of its flows into the ground water underlying the beds. The gross concentration of beta and gamma-emitters in it was 4 percent of the applicable radiation standard. Tritium, which is measured separately, was 0.3 percent of its standard.

Of the input from the sand filter beds to the Peconic River, 65 percent permeated into the ground water underlying the stream bed between the point of release and the laboratory perimeter, while 35 percent flowed over the measuring weir at the boundary. The gross beta and gamma-emitter concentration at the site boundary was 2 percent of the AEC standard, while that of tritium was 0.3 percent of its standard.

At downstream locations, the largest yearly average gross beta concentration in monthly grab samples was 0.7 percent of the AEC standard, while that of tritium was 0.1 percent of its standard. The downstream gross beta concentrations were not significantly different from those measured at remote "control" stream locations.

Seasonal sampling of Peconic River bottom sediments, stream vegetation and of miscellaneous aquatic fauna indicated that small concentrations of cobalt-60 (<1000 pCi/kg), and a slight excess (<10 000 pCi/kg) of cesium-137 above prevailing fallout background, were present in some samples obtained in the upper reaches of the Peconic, onsite and a few miles downstream. These concentrations are insignificant (<1 percent) relative to calculated concentration guides.

Routine grab samples from the laboratory's potable and cooling water supply wells disclosed no consistent differences between those upstream in ground water flow and those downstream from the principal laboratory facilities. The gross beta concentration of the large volume of cooling water released to onsite sumps was only very slightly above that of the supply wells.

Ground water surveillance was conducted adjacent to identified areas from which there is a potential for the migration of radioactivity. Immediately adjacent to the sand filter beds and the Peconic River onsite, gross alpha, gross beta, strontium, and tritium concentrations up to a few percent of the applicable radiation protection standards were found.

Onsite in wells adjacent to a decontamination facility drain sump, and adjacent to the solid waste disposal area, a few gross beta, strontium-90 and cesium-137 concentrations were found in excess of offsite radiation protection standards. However, these appear to be very local, and concentrations in perimeter wells were generally only a few percent of the standards.

Monthly milk samples were obtained from two nearby dairy farms. No significant differences between these and those generally prevailing in the northeast United States were apparent. Two sets of grass and soil samples were also collected from these and three other farms, as well as from perimeter and onsite locations. There was no significant difference between offsite samples generally downwind and those generally upwind of Brookhaven. A possible small excess of cesium-137 was apparent at the BNL northeast perimeter and adjacent to the solid waste disposal area, compared to other samples.

Recent coverage in *Radiation Data and Reports:*

Period	Issue
July–December 1970	February 1973

REFERENCES

(1) U.S. ATOMIC ENERGY COMMISSION. AEC manual Standards for Radiation Protection, Chapter 0524. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1968).

(2) WARREN, M. A., W. deLAGUNA, and N. J. LUSCZYNSKI. Hydrology of Brookhaven National Laboratory and vicinity. Geo Survey Bulletin 1156–C (1968).

(3) ENVIRONMENTAL PROTECTION AGENCY, OFFICE OF RADIATION PROGRAMS. Milk surveillance, December 1971. Radiat Data Rep 13:195–203 (April 1972).

(4) BENTLEY, W G. Radioactivity in air, milk, and water. Environmental Radiation Bulletins 71–1; 71–2; 71–3; 71–4. State of New York Department of Environmental Conservation.

(5) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

2. Oak Ridge Area,[3] January–December 1971

Union Carbide Nuclear Division
Oak Ridge, Tenn.

The Oak Ridge area incorporates three separate operating facilities, the Oak Ridge National Laboratory (ORNL), the Oak Ridge Gaseous Diffusion Plant (ORGDP), and the Y-12 Plant, all of which are operated by Union Carbide Corporation, Nuclear Division. In addition, two smaller Atomic Energy Commission (AEC) facilities are in the area—the UT-AEC Agricultural Research Station and Oak Ridge Associated Universities.

Oak Ridge National Laboratory is a large multipurpose research laboratory whose basic mission is the discovery of new knowledge, both basic and applied, in all areas related to nuclear energy. To accomplish this mission, the laboratory conducts research in all fields of modern science and technology. The laboratory's facilities consist of nuclear reactors, chemical pilot plants, research laboratories, radioisotope production laboratories, and support facilities.

The Oak Ridge Gaseous Diffusion Plant is a complex of production, research, development, and supporting facilities, distributed over a 640-area of eastern Tennessee. The primary mission of the plant is the enrichment of uranium hexafluoride in the uranium-235 isotope, with the performance of other atomic energy related activities as required by the Atomic Energy Commission. The principal process facilities are the five gaseous diffusion cascade buildings, portions of which are now on standby. These are supplemented by about 70 support buildings and facilities (maintenance, supply stores, administration, cafeteria, data processing, etc.). Union Carbide Corporation, Nuclear Division has been responsible for operating the Oak Ridge Gaseous Diffusion Plant since its inception.

The Oak Ridge Y-12 Plant occupies approximately 500 acres and is located immediately adjacent to the city of Oak Ridge, Tenn. It is about 2½ miles long and ¼ mile wide. The Y-12 Plant has four major responsibilities: (1) production of atomic weapons components, (2) fabrication support for weapon design agencies, (3) support for the Oak Ridge National Laboratory, and (4) support and assistance to other government agencies. Activities associated with these functions include the production of lithium compounds, the recovery of enriched uranium from unirradiated scrap material and

[3] Summarized from Environmental Monitoring Report, U.S. Atomic Energy Commission, "Oak Ridge Facilities, Calendar Year 1971."

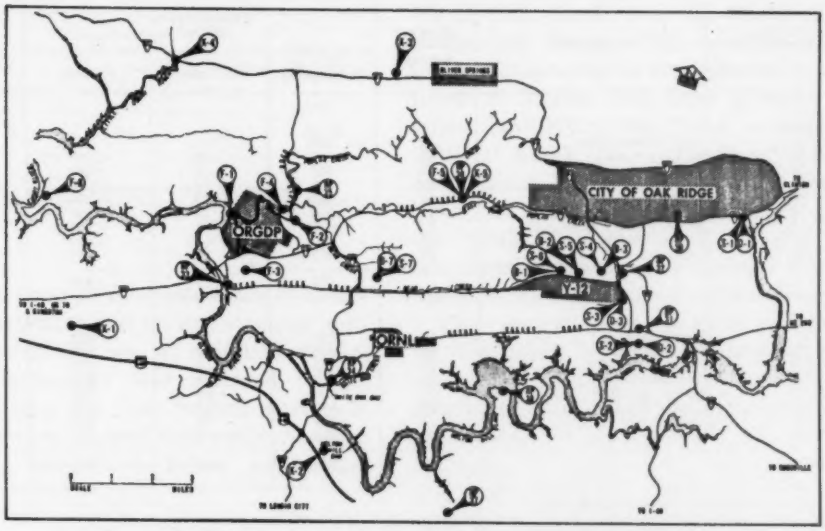

Figure 6. Locations of air monitoring stations, Oak Ridge area

the fabrication of uranium and other materials into finished parts and assemblies.

Air monitoring

Atmospheric contamination by radioactive materials occurring in the general environment of east Tennessee is monitored by two systems of monitoring stations. One system consists of nine stations (HP-31 through HP-39) which encircle the perimeter of the Oak Ridge area and provides data for evaluating releases from Oak Ridge facilities to the immediate environment (figure 6). A second system consists of eight stations (HP-51 through HP-58) encircling the Oak Ridge area at distances from 12 to 75 miles (figure 7). This system provides background data to aid in evaluating local conditions. Sampling for radioactive particulates is carried out by passing air continuously through filter papers. Filter papers are evaluated by gross beta and gross alpha counting techniques for normal operations. More detailed analyses are performed when concentrations in the environment are significantly above normal. Airborne radioactive iodine is monitored by passing air continuously through cartridges containing activated charcoal. Charcoal cartridges are evaluated for radioactive iodine by gamma spectrometry.

Data on the concentrations of radioactive materials in air in the Oak Ridge and surrounding areas are given in tables 19 through 21. The average gross beta concentrations of radioactivity from particulates in air measured by the perimeter and remote monitoring systems were less than 0.23 percent and 0.23 percent, respectively, of the AEC standards (*6*), for individuals in uncontrolled areas (table 19). The average gross alpha concentrations were less than 0.05 percent of the concentration guide for natural uranium in both systems (table 20). The average concentration of iodine-131 measured by the perimeter air monitoring system was less than 0.01 percent of the inhalation concentration guide for individuals in uncontrolled areas (table 21).

Table 19. Long-lived gross beta radioactivity in airborne particulates, ORNL, January-December 1971

Station number	Location	Number of samples	Concentration (fCi/m³)			Percent of AEC standard [c]
			Maximum [a]	Minimum [b]	Average	
Perimeter stations [d]						
HP-31	Kerr Hollow Gate	52	640	35	220	0.22
HP-32	Midway Gate	52	720	<3	<230	<.23
HP-33	Gallaher Gate	52	820	<3	<200	<.20
HP-34	White Oak Dam	52	700	<3	<220	<.22
HP-35	Blair Gate	52	840	23	230	.23
HP-36	Turnpike Gate	[e] 249	800	10	260	.26
HP-37	Hickory Creek Bend	52	690	<3	<190	<.19
HP-38	East of EGCR	52	660	<3	<230	<.23
HP-39	Townsite	52	880	13	250	.25
Average			750	<11	<230	<.23
Remote stations [f]						
HP-51	Norris Dam	51	720	28	220	0.22
HP-52	Loudoun Dam	51	760	28	230	.23
HP-53	Douglas Dam	52	650	3	220	.22
HP-54	Cherokee Dam	51	750	33	230	.23
HP-55	Watts Bar Dam	52	820	29	250	.25
HP-56	Great Falls Dam	52	670	24	240	.24
HP-57	Dale Hollow Dam	52	680	34	220	.22
HP-58	Knoxville	48	670	4	220	.22
Average			720	23	230	.23

[a] Maximum weekly average concentration.
[b] Minimum weekly average concentration—minimum detectable level is 5 pCi/sample.
[c] AEC standard is 100 pCi/m³ for unidentified radionuclides (AEC Manual, Appendix 0524, Annex A, Table II).
[d] Figure 6.
[e] Samples collected 5 days per week.
[f] Figure 7

Table 20. Long-lived gross alpha radioactivity in air, ORNL, January-December 1971

Station number	Location	Number of samples	Concentration (fCi/m³)			Percent of AEC standard [c]
			Maximum [a]	Minimum [b]	Average	
Perimeter stations: [d]						
HP-31	Kerr Hollow Gate	52	5	<1	<1	<0.05
HP-32	Midway Gate	52	5	<1	<2	<.10
HP-33	Gallaher Gate	52	7	<1	<1	<.05
HP-34	White Oak Dam	52	4	<1	<1	<.05
HP-35	Blair Gate	52	5	<1	<1	<.05
HP-36	Turnpike Gate	[e] 249	14	<1	<4	<.20
HP-37	Hickory Creek Bend	52	2	<1	<1	<.05
HP-38	East of EGCR	52	5	<1	<2	<.10
HP-39	Townsite	52	3	<1	<1	<.05
Average			6	<1	<1	<.05
Remote stations [f]:						
HP-51	Norris Dam	51	3	<1	<1	<0.05
HP-52	Loudoun Dam	51	4	<1	<1	<.05
HP-53	Douglas Dam	52	5	<1	<1	<.05
HP-54	Cherokee Dam	51	4	<1	<1	<.05
HP-55	Watts Bar Dam	52	5	<1	<1	<.05
HP-56	Great Falls Dam	52	3	<1	<1	<.05
HP-57	Dale Hollow Dam	52	3	<1	<1	<.05
HP-58	Knoxville	48	5	<1	<1	<.05
Average			4	<1	<1	<0.05

[a] Maximum weekly average concentration.
[b] Minimum weekly average concentration—minimum detectable level is 2 pCi/sample.
[c] AEC standard is 2.0 pCi/m³ for natural uranium (AEC Manual, Appendix 0524, Annex A, Table II).
[d] See figure 6.
[e] Samples collected 5 days per week.
[f] See figure 7.

Table 21. Concentration of iodine-131 in air as measured by the perimeter air monitoring stations,[a] ORNL January-December 1971

Number of samples	Concentration (fCi/m³)			Percent of AEC standard [c]
	Maximum	Minimum [b]	Average	
468	61	<6	<11	<0.01

[a] See figure 6.
[b] Minimum detectable amount of iodine-131 is 10 pCi/sample.
[c] AEC standard is 100 pCi/m³ (AEC Manual, Appendix 0524, Annex A, Table II).

The uniform level of filterable activity measured by the perimeter and remote stations indicated that the activity was of nonplant origin. While some iodine-131 was released to the atmosphere during the year, measurements in the Oak Ridge area showed that environmental concentrations were well below established standards.

Water monitoring

Liquid wastes originating at the three major Oak Ridge facilities are discharged, after treatment, to White Oak Creek, Poplar Creek, East Fork Poplar Creek, and Bear Creek which are small tributaries to the Clinch River.

A continuous proportional sample is collected at White Oak Dam (Station W-1), which is the last onsite control point prior to the entry of White Oak Creek into the Clinch River, and composited for monthly analysis. Continuous proportional samples are collected in the Clinch River at Melton Hill Dam (Station C-2) 2.3 miles above White Oak Creek outfall and at the ORGDP water intake (Station C-3) 6.3 miles downstream from the entry of White Oak Creek. A grab sample is collected daily from the Clinch River at Center's Ferry near Kingston, Tenn. (Station C-5), figure 7. Clinch River samples are composited for quarterly analysis.

The concentrations of radionuclides present in detectably significant amounts are determined by specific radionuclide analysis and gamma spectrometry. The concentration of each radionuclide is compared with its respective concentration guide (CG) value as specified in the AEC Manual, Appendix 0524, and the resulting fractions are summed to obtain the percent of the AEC standard in the Clinch River.

Water samples are collected in Poplar Creek upstream of the ORGDP (Station P-1), in Poplar Creek downstream from the ORGDP waste discharges (Station P-2), and in the Clinch River downstream from the Poplar Creek outfall (Station C4) (figure 7). Semi-

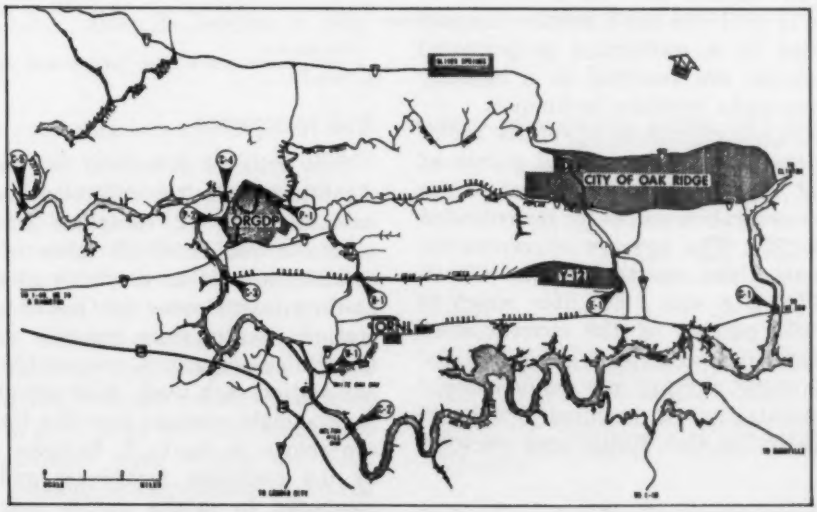

Figure 7. Locations of stream monitoring stations, Oak Ridge area

Table 22. Radionuclides in the Clinch River, ORNL, January-December 1971

Sampling location	Number of samples	Range	Concentration (pCi/liter)							Percent of AEC standard [a]
			^{90}Sr	^{144}Ce	^{137}Cs	$^{103,-106}Ru$	^{60}Co	^{95}Zr-Nb	Tritium	
C2 CRM 23.1 [a]	4	Maximum	0.7	0.5	0.3	1.8	0.4	0.2	<1000	
		Minimum	.3	.1	<.1	.7	.1	<.1	<1000	
		Average	.5	.3	<.1	1.2	.3	<.1	<1000	<0.21
W1 CRM 20.8 [b]	12	Maximum	1.8	<.1	.6	.3	.5	<.1	5160	
		Minimum	.2	<.1	<.1	<.1	<.1	<.1	510	
		Average	.5	<.1	.1	<.1	<.1	<.1	1150	<.20
C3 CRM 14.5 [a]	4	Maximum	2.7	.7	.0	4.8	.9	.5	6580	
		Minimum	1.4	<.1	.6	1.0	.3	<.1	<1000	
		Average	1.8	<.3	1.3	2.7	.6	<.2	<2970	<.75
C5 CRM 4.5 [a]	4	Maximum	1.4	.5	1.3	2.3	1.9	.3	5180	
		Minimum	.5	.1	.5	.5	.2	<.1	<1000	
		Average	1.0	.3	.9	2.0	.8	<.1	<2210	<.45

[a] Measured values.
[b] Values given for this location are calculated values based on the concentrations measured at White Oak Dam and the dilution afforded by the Clinch River. They do not include radioactive materials (e.g., fallout) that may enter the river upstream of White Oak Creek outfall (CRM 20.8).
[c] Applicable concentration guides and the method for calculating percent of concentration guide for a known mixture of radionuclides are given in AEC Manual, Appendix 0524, Annex A.

annual grab samples are collected in Poplar Creek to verify the continued compliance demonstrated by continuous samples taken over a 12-year period. A continuous sample is collected in the Clinch River and composited over a 3-month period for analysis. Samples are analyzed for uranium by the fluorometric method.

Continuous proportional water samples are collected at the outlet of New Hope Road on East Fork Poplar Creek (Station E-1). Weekly grab samples were collected on Bear Creek (Station B-1) during the first 9 months of 1971 (figure 7) while the last 3 month's samples were obtained by a continuous proportional sampler. Samples are analyzed on a monthly basis by gross alpha counting techniques.

The average concentrations of specific radionuclides in the Clinch River at all points of measurement were less than 1 percent of the applicable concentration guides for uncontrolled areas (table 22). The average concentration of transuranic alpha emitters in the Clinch River at CRM 20.8 was 5 fCi/liter which is less than 0.01 percent of the concentration guide for water in uncontrolled areas containing an unknown mixture of radionuclides.[4] Average concentrations of uranium in the surface streams in the Oak Ridge area were no greater than 1.2 percent of the applicable concentration guide for uncontrolled areas (table 23).

Table 23. Uranium concentration in surface streams ORNL, January-December 1971

Station number [a]	Location	Number of samples	Concentration (pCi/liter)			Percent of AEC standard [b]
			Maximum	Minimum	Average	
P-1	Poplar Creek	2	40	10	25	0.1
P-2	Poplar Creek	2	130	13	71	.3
C-4	Clinch River	4	6	0	3	<.1
E-1	East Fork Poplar Creek	12	400	160	240	1.2
B-1	Bear Creek	12	700	100	230	1.2

[a] See figure 8.
[b] AEC standard is 20 nCi/liter (AEC Manual, Appendix 0524, Annex A, Table II).

Milk monitoring

Raw milk is monitored for iodine-131 and strontium-90 by the collection and analysis of samples from 12 sampling stations located within a radius of 50 miles of Oak Ridge. Samples are collected weekly at each of eight stations located near the Oak Ridge area. Four stations, located more remotely with respect to Oak Ridge operations, are sampled at a rate of one station each week. Milk sampling locations for the eight stations near the Oak Ridge area are shown in figure 8. Samples are analyzed by ion exchange techniques and results are compared to intake guides specified by the Federal Radiation Council (FRC) (*7*).

[4] AEC Radiation Protection Standard—100 pCi/liter (*16*).

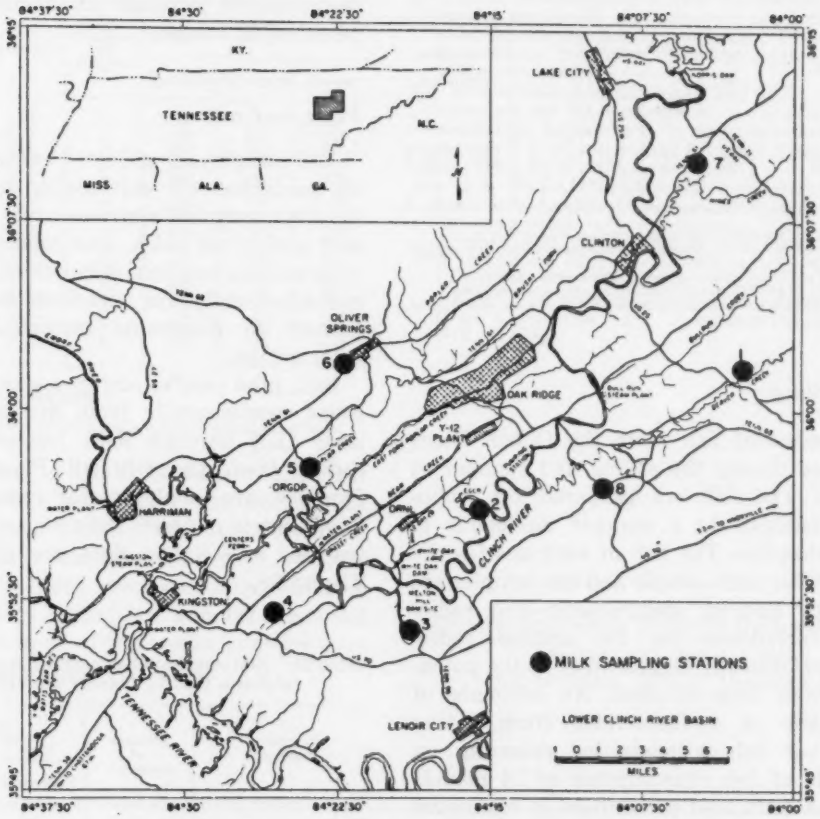

Figure 8. Locations of milk sampling stations, Oak Ridge area

The average concentrations of iodine-131 and strontium-90 in raw milk are given in tables 24 and 25. If one assumes the average intake of milk per individual to be 1 liter per day, the average concentration of iodine-131 in the milk in the immediate environs of the Oak Ridge area was just above the lower limit of FRC Range II. The average concentration in the environs remote from Oak Ridge was within FRC Range I. The average concentrations of strontium-90 in milk from both the immediate and remote environs were within the FRC Range I. The average concentrations measured in the Oak Ridge area do not differ significantly from the values in the southeastern United States reported by the Environmental Protection Agency's Pasteurized Milk Network.

Table 24. Concentration of iodine-131 in raw milk, ORNL January-December 1971

Location	Number of samples	Concentration (pCi/liter)			Comparison with standard [b]
		Maximum	Minimum [a]	Average	
Immediate environs [c]	389	21	<10	<10.1	FRC Range II
Remote environs	38	<10	<10	<10	FRC Range I

[a] Minimum detectable concentration of iodine-131 is 10 pCi/liter.
[b] Applicable FRC standard, assuming 1 liter per day intake:
Range I: 0 to 10 pCi/liter—adequate surveillance required to confirm calculated intakes.
Range II: 10 to 100 pCi/liter—active surveillance required.
Range III: 100 to 1 000 pCi/liter—positive control action required.
Note: Upper limit of Range II can be considered the concentration guide.
[c] See figure 8.

Table 25. Concentration of strontium-90 in raw milk ORNL, January-December 1971

Location	Number of samples	Concentration (pCi/liter)			Comparison with standard [b]
		Maximum	Minimum [a]	Average	
Immediate environs [c]	389	32	2.4	11.4	FRC Range I
Remote environs	38	15	6.8	9.4	FRC Range I

[a] Minimum detectable concentration of strontium-90 in milk is 2 pCi/liter.
[b] Appicable FRC standard, assuming 1 liter per day intake:
Range I: 0 to 20 pCi/liter—adequate surveillance required to confirm calculated intakes.
Range II: 20 to 200 pCi/liter—active surveillance required.
Range III: 200 to 2000 pCi/liter—positive control action required.
Note: Upper limit of Range II can be considered the concentration guide.
[c] See figure 8.

Fish sampling

Two species of fish from the Clinch River are sampled during the spring and summer of each year. The fish are prepared for radiochemical analysis in a manner analogous to human utilization. Ten fish of each species are composited for each sample and the samples are analyzed by gamma spectrometry and radiochemical techniques for the critical radionuclides contributing significantly to the potential radiation dose to man. An estimate of man's intake of radionuclides from eating Clinch River fish is made by assuming an annual rate of fish consumption of 14 pounds (*8*) and the estimated percentage of maximum permissible intake is calculated by assuming a maximum permissible intake of radionuclides from eating fish to be comparable to a daily intake of 2.2 liters (*9*) of water containing the concentration guide of the radionuclides in question, for a period of 1 year.

Data on the concentrations of radionuclides in Clinch River fish are given in table 26. The levels measured were less than 1 percent of that required to obtain an estimated maximum permissible intake.

Table 26. Radionuclide content of Clinch River fish ORNL, January-December 1971

Species	Number of samples [a]	Concentration (pCi/kg wet weight)			Estimated percent of MPI [b]
		^{90}Sr	^{106}Ru	^{137}Cs	
White crappie	1	195	<180	343	<0.38
Small mouth buffalo	1	108	<315	336	<.32

[a] Composite of 10 fish in each species.
[b] Maximum permissible intake—assumes intake of radionuclides from eating fish to be comparable to a daily intake of 2.2 liters of water for the year containing the concentration guide level of the radionuclides in question.

Flora and soil

Soil samples are collected annually from near the perimeter air monitoring stations (figure 6). Four samples, approximately 8 cm in diameter and 1 cm thick, are collected in a 1 m^2 area at each location, composited, and analyzed radiochemically for uranium and plutonium content to determine historical background information.

Soil, pine needle, and grass samples are collected semiannually from five sampling locations (K-1 through K-5) located on a 5-mile radius from the ORGDP Plant (figure 6). Samples are analyzed for uranium by the fluorometric method. Data on uranium concentrations in soil and flora are given in tables 27 and 28.

Table 27. Soil samples taken near perimeter air monitoring stations, ORNL, January-December 1971

Sampling location [a]	Number of samples [b]	Concentration (fCi/g dry soil) [c]	
		Plutonium (α)	Uranium
HP-31	1	33	110
HP-32	1	28	70
HP-33	1	24	230
HP-34	1	38	230
HP-35	1	47	320
HP-36	1	24	290
HP-37	1	14	140
HP-38	1	28	140
HP-39	1	52	630

[a] See figure 6.
[b] Four samples, approximately 8 cm in diameter and 1 centimeter thick, collected in a 1 m^2 area at each location and composited for analysis.
[c] Applicable concentration guides for soil contamination have not been established.

Summary

The monitoring program for the Oak Ridge area includes sampling and analysis of air, water from surface streams, several food products, flora, and soil from radioactive materials.

Surveillance of radioactivity in the Oak Ridge environs indicated that the atmospheric concentrations of radioactivity were not significantly different from other areas in east Tennessee. Concentrations of radioactivity in the

Table 28. Uranium in soil, pine needles, and grasses at 5-mile radius from ORGDP, January-December 1971

Substance	Location [a]	Number of samples	Concentration (fCi/g)		
			Maximum	Minimum	Average
Soil [b]	K–1	2	700	150	425
	K–2	2	650	350	500
	K–3	2	400	350	375
	K–4	2	450	400	425
	K–5	2	650	400	525
Pine needles [c]	K–1	2	100	50	75
	K–2	2	100	35	67
	K–3	2	200	35	117
	K–4	2	200	35	117
	K–5	2	250	35	142
Grass [c]	K–1	2	350	50	200
	K–2	2	250	100	175
	K–3	2	150	35	92
	K–4	2	200	50	125
	K–5	2	300	35	167

[a] See figure 6.
[b] Top 5 cm of soil on a dry basis.
[c] Dry basis.
Note: Applicable guides for flora and soil have not been established.

Clinch River and in fish collected from the river were less than 1 percent of the permissible concentration and intake guides for individuals in neighboring populations. Only very low level radioactivity is being released to the environment from plant operations and the resulting concentrations in all of the media sampled were well below permissible standards.

REFERENCES

(6) U.S. ATOMIC ENERGY COMMISSION. AEC manual standards for radiation protection, Chapter 0524, Annex A. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (February 1969).

(7) FEDERAL RADIATION COUNCIL. Background materials for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

(8) U.S. DEPARTMENT OF AGRICULTURE. Department of Agriculture, agricultural statistics, 1969. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1969).

(9) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Report of ICRP Committee II on permissible dose for internal radiation, ICRP Publication No. 2. Pergamon Press, New York, N.Y. (1959).

Previous coverage in *Radiation Data and Reports:*

Period	Issue
July–December 1970	December 1973

3. Pinellas Peninsula Plant [5] July–December 1971

General Electric Company
St. Petersburg, Fla.

The Pinella Peninsula Plant (figure 9) is an electronic component production facility. The plant maintains an environmental monitoring program to measure the levels of radioactive environmental contamination associated with plant effluents. These measurements serve as an index of the effectiveness of the plant's contamination control measures. Sewer effluent, surface water, milk and air within 6 miles of the plant are monitored for radioactivity. The radioactivity concentrations, weighted by atmospheric and stream dilution factors, are compared against the AEC standards for continuous nonoccupational exposure as presented in AEC Manual chapter 0524.

Combined sewer effluent

Waste water discharges from the plant were routinely sampled for radioactive material content at the site's boundary. A total of 147 samples were obtained and analyzed for tritium content. In those instances where detectable concentrations occurred, the radioactivity resulted from controlled releases. Radioactivity

[5] Summarized from "Environmental Monitoring Report, Pinellas Plant, 1971."

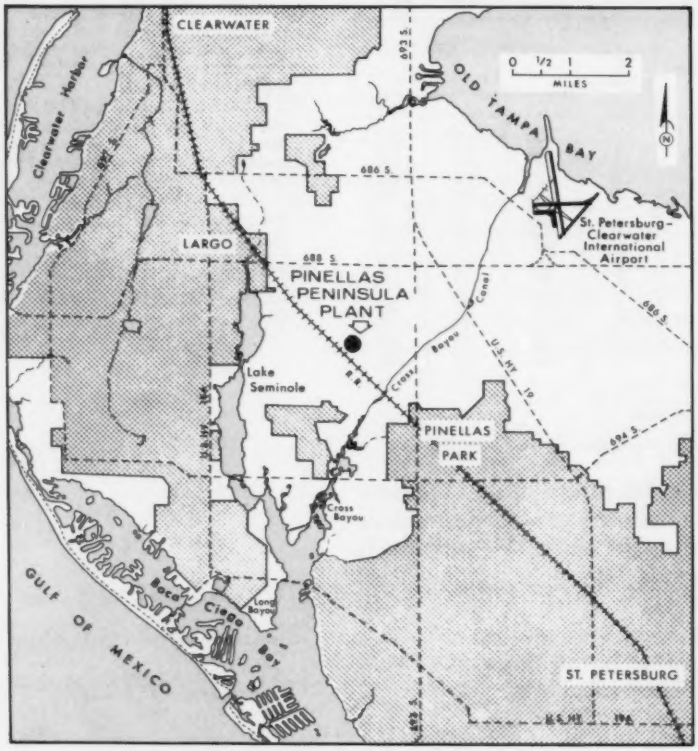

Figure 9. Location of the Pinellas Peninsula Plant

releases from the process waste system into the plant's water effluents resulted in an average tritium concentration for the period, of less than 0.6 percent of the AEC standard for continuous nonoccupational exposure.

Milk samples

Analyses of 10 raw milk samples provided by the Pinellas County Health Department from the one local diary farm revealed no detectable concentrations (<20 nCi/liter) of tritium.

Air samples

A total of four ambient air samples were obtained downwind from the plant site for tritium analysis during times of radioactivity releases. Analyses of these samples revealed that the maximum level, occurring over a period of 30 minutes, represented 0.3 percent of the tritium oxide in air concentration for continuous nonoccupational exposure.

Surface water

There were no indications of tritium in 138 routine surface water samples collected from areas surrounding the plant. These sample locations represent an area up to 6 miles in all directions from the plant site, and are not related to the waste water effluent from the plant.

Previous coverage in *Radiation Data and Reports:*

Period	Issue
January–June 1971	September 1972

Erratum

On page 101 of the Savannah River Plant article in the February 1974 issue of *Radiation Data and Reports*, a typographical error occurred in the second paragraph under the subheading *"Deer."* The fourth sentence in this paragraph should read:

"Edible meat from the deer containing 48 pCi/g would weigh about 40 pounds and would therefore contain about 0.87 μCi of cesium-137."

Reported Nuclear Detonations, June 1974

(Includes seismic signals presumably from foreign nuclear detonations)

The Peoples Republic of China set off a nuclear explosion in the atmosphere at about 2:00 a.m. EDT on June 17, 1974, at their Lop Nor nuclear test area in northwest China. The yield was in the range of 200 kilotons to 1 megaton.

The United Kingdom announced that an underground nuclear test had been conducted sometime during June 1974 at the Nevada Test Site in the United States. No yield was announced.

There were no nuclear detonations for the United States reported by the U.S. Atomic Energy Commission for June 1974.

Not all of the nuclear detonations in the United States are announced immediately, therefore, the information in this section may not be complete. A complete list of announced U.S. nuclear detonations may be obtained upon request from the Division of Public Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ENVIRONMENTAL RADIATION EFFECTS OF NUCLEAR FACILITIES IN NEW YORK STATE. *Michael S. Terpilak* and *Bruce L. Jorgensen. Radiation Data and Reports, Vol 15,* July 1974, pp. 375–400.

The annual quantities and types of radioactive materials released from three operating nuclear electric generating facilities, a national laboratory, and a nuclear fuels reprocessing facility are presented and discussed. The period of interest spans the years 1969 through 1972 with some additional data for those facilities operating before 1969. Release quantities have been well controlled, considering the nature and vintage of the operations.

Results of environmental surveillance relying most heavily on the activities of the New York State Department of Environmental Conservation, are presented. Observations at Indian Point Station Unit 1 and at Nuclear Fuel Services have led to the discovery of several facility-related radioisotopes in environmental media. These two facilities are of comparatively early vintage, have produced slightly larger amounts of waste materials and have been the subject of more comprehensive studies than others in the State.

Dose consequences to hypothetical individuals and to populations within 50 miles of the facilities are addressed. It should be stressed that all individual doses presented are hypothetical. Doses via the drinking water and cow's-milk-pathways are particularly conservative. In each case, these hypothetical doses are at least an order of magnitude or more greater than the known worst case. No excessive exposure levels are known to have existed. All operations have resulted in postulated exposure levels well within applicable regulations or guidelines, generally being a small percentage of these values. Population doses have been surprisingly consistent through the period of interest. They are insignificant in comparison to the dose to the population of the State from natural or medical sources.

KEYWORDS: Air, background radiation, cesium-137, fish, milk, New York, nuclear power generating plants, radioactive waste, silt, vegetation.

CALCULATED FIELD INTENSITIES NEAR A HIGH POWER UHF BROADCAST INSTALLATION. *Richard A. Tell and John C. Nelson, Radiation Data and Reports, Vol. 15,* July 1974, pp. 401–410.

A UHF transmitter site in the Washington, D.C. area, which is used cooperatively by two UHF television stations, was chosen for calculations of effective radiated power (ERP), field strength, and power density. Using the specifications for the two broadcasting stations, field strengths and power densities were calculated and presented graphically.

The calculated power densities for this broadcasting installation showed that the exposure values fall very sharply as the distance from the tower increases to about 1 mile. At distances beyond 0.5 miles, the maximum exposure values calculated were about 2.7 $\mu W/cm^2$ occurring at 0.5, 3.3, and 4.5 miles. As the height above ground at the receiving point is increased, the exposure value generally increases.

Based on the calculations for the 135 degree radial and the computed population distribution, it appears that approximately 86 000 people reside in an area within which the estimated exposure value is 1 $\mu W/cm^2$ or more.

KEYWORDS: Antenna, broadcasting station, calculations, field intensities, ultra high frequency (UHF), Washington, D.C.

ANALYSIS OF RADIATION EXPOSURES ON OR NEAR URANIUM MILL TAILINGS PILES. *Keith J. Schiager. Radiation Data and Reports, Vol. 15,* June 1974, pp. 411–425.

Potential radiation exposures from abandoned uranium mill tailings piles may be predicted in a general manner using minimal input data. If the average radium concentration in the tailings C_{Ra} is known, the external gamma exposure rate over the tailings can be estimated from: X (μR/h) $\cong$ 2.5 C_{Ra} (pCi/g). The radon emanation rate can also be estimated as: ϕ (pCi Rn/m^2–s) $\cong$ 1.6 C_{Ra} (pCi/g). The reductions of exposure rates that can be achieved by covering the tailings with earth or concrete also are discussed. Radon progeny inhalation exposures depend upon the dispersion rate of radon in the atmosphere and the time available for progeny ingrowth. Meteorological data for the site are required for making reliable predictions of inhalation exposures. It is shown, however, that contributions to the average annual outdoor radon progeny concentrations exceeding 0.003 WL are very unlikely on or near any tailings pile. The methods used to analyze potential radiation exposures are illustrated by a case study on one abandoned tailings pile.

KEYWORDS: exposure, inhalation, meteorology, radon, uranium mill tailings pile, Utah.

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July 1974

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